The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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American Volume

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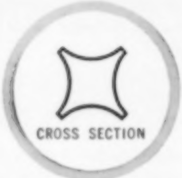

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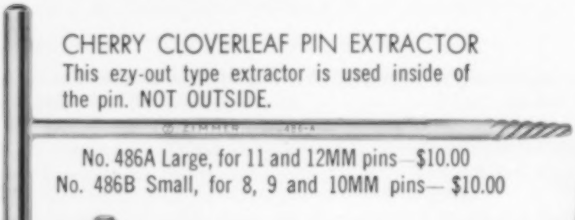

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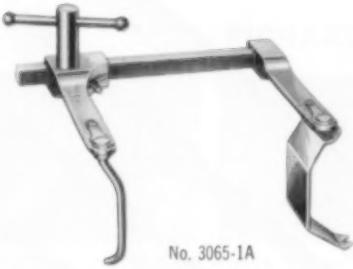

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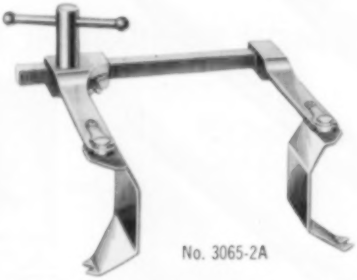

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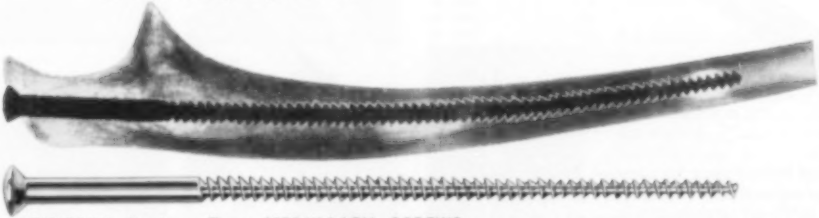

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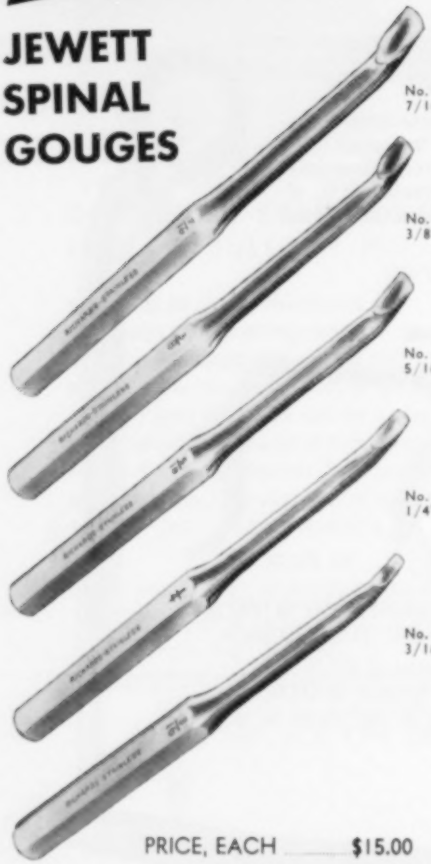

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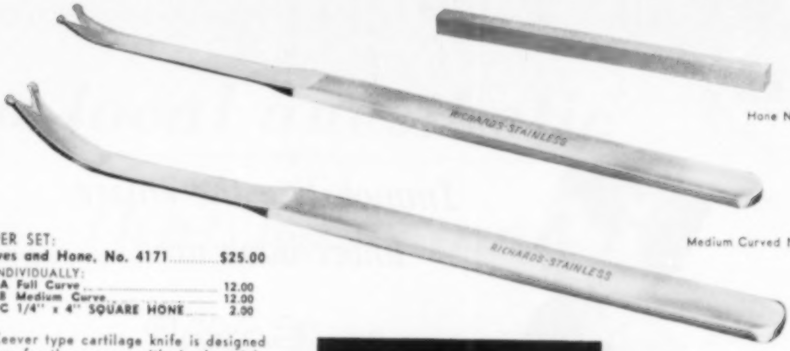

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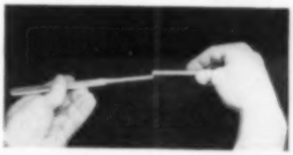

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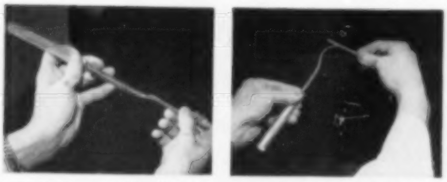

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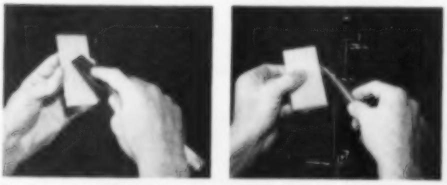

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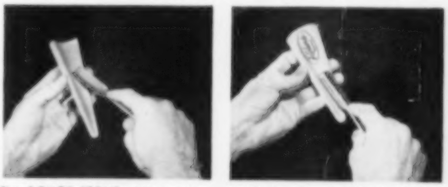

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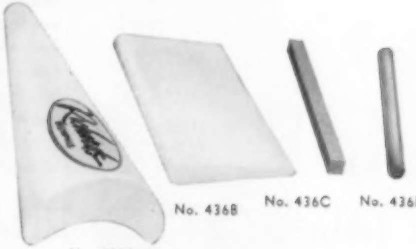

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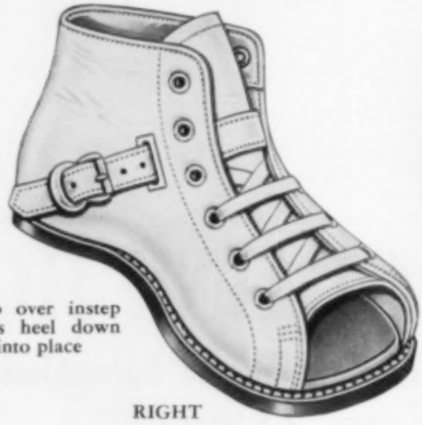
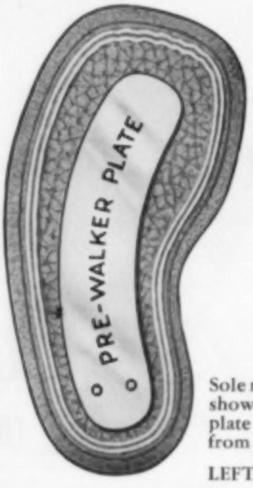


Strap over instep holds heel down into place

RIGHT



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LEFT

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As the infant progresses to the point of walking or standing alone and further corrections are required, then the regulation Sabel Club Foot shoe can be used until the fixation desired has taken place.

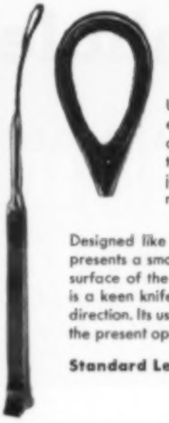
I. SABEL, Inc.
1207 Chestnut Street Philadelphia 7, Pa.

BOOKLET WITH COMPLETE DETAILS ALSO DEALERS' NAMES UPON REQUEST

Made Exclusively by

THOMPSON BROS. SHOE CO., Brockton, Massachusetts

SAFER and QUICKER MENISECTOMIES with BOWEN Instruments



Grover Menisectome

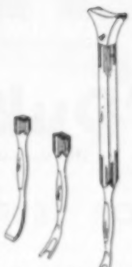
Used through any arthrotomy exposure and on either semilunar cartilage, it guarantees the integrity of all structures within the joint and permits complete removal of either meniscus.

Designed like a large intra-uterine curette, it presents a smooth rounded guard on the outer surface of the ring, the inner margin of which is a keen knife edge permitting cutting in any direction. Its use will shorten by about one-third the present operating time.

Standard Length: 8½" • **No. 128**

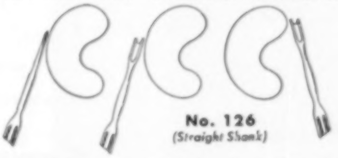
Smillie Cartilage Sets

Designed with handles that do not obscure field of vision. Longer back always rests on tibial table. Beaked knife divides the peripheral attachments of the medial meniscus. Also divides the central attachment of the posterior horn of the lateral meniscus. Second beaked knife used for the same purpose, also to divide the central attachment of the posterior horn of the medial meniscus. Chisel mobilizes middle third of the meniscus.



No. 108
(Curved Shank)

ILLUSTRATIONS SHOW POSITIONS OF KNIVES IN USE



No. 126
(Straight Shank)

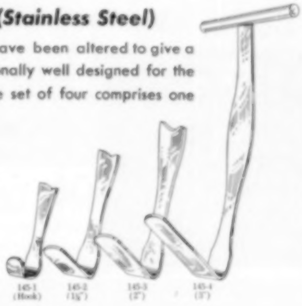
Smillie Knee Joint Retractor Set *(Stainless Steel)*

The angles of the blades and the modified handles of these retractors have been altered to give a better grip and keep the fingers away from the incision. They are exceptionally well designed for the removal of menisci and for use in practically all knee joint operations. The set of four comprises one hook and three with blade lengths from 1½ inches to 3 inches.

FEATURES: "Sure grip handles for perfect control." • "Hardened and tempered to rigid specifications." • "Useful retractors for many other surgical procedures."

No. 145 Knee Joint Retractor Set—$30.00
(Four Pieces)

Priced Individually at $8.00 each.



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For the dispensing of alcohol and other cleansing liquids.

Patent Applied For

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- *To Use, Just Press on Metal Plate!*

ONLY
$1.50

BOWEN & COMPANY, INC.

P. O. BOX 5818
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Brand of trichloroethylene U.S.P. (Blue)

"Duke"® University Inhaler

No. 3160 Model-M

FOR SELF-ADMINISTERED INHALATION ANALGESIA

IN OBSTETRICS

IN MINOR SURGERY

IN PEDIATRICS

■ Notably safe and effective

"Trilene," self administered with the "Duke" University Inhaler, under proper medical supervision, provides highly effective analgesia with a relatively wide margin of safety.

■ Convenient to administer

The "Duke" University Inhaler (Model-M) is specially designed for economy, facility of handling, and ready control of vapor concentration.

■ Special advantages

- Induction of analgesia is usually smooth and rapid with minimum or no loss of consciousness
- Patients treated on an ambulatory basis can usually leave the doctor's office or hospital within 15 to 20 minutes
- Inhalation is automatically interrupted if unconsciousness occurs

"Trilene" *alone* is recommended only for analgesia, not for anesthesia nor for the induction of anesthesia. Epinephrine is contraindicated when "Trilene" is administered.

"Trilene" is available in 300 cc. containers, 15 cc. tubes, and 6 cc. ampuls.

Ayerst Laboratories • New York, N. Y. • Montreal, Canada

5516

Ayerst Laboratories make "Trilene" available in the United States by arrangement with Imperial Chemical (Pharmaceuticals) Limited.

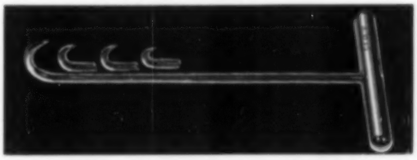
What's New at DePuy for the Orthopedic Surgeon!

DePuy HAND CHISEL SET

This newly designed set is comprised of nine chisels and a mallet, particularly adapted for use in hand and foot surgery. Made of highest quality stainless steel, tempered and hardened to afford lasting sharpness to the cutting edges. Each chisel has long handle for firm grip. They are well balanced for safe, sure handling. Mallet is of well balanced design with wide striking face, and is constructed entirely of stainless steel. No. 629 (complete set, including handy carrying case).

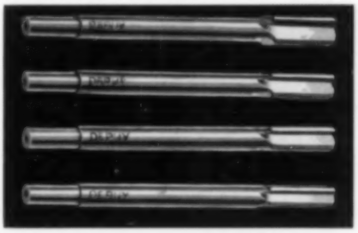
DePuy BONE CURETTES

New, improved curettes designed for easy, accurate handling. Highly polished oval bowls have finely ground edges for lasting sharpness. Constructed of stainless steel with hollow handle for perfect balance and light weight. Thumb rest on handle assures no-slip grip. Available in nine sizes, 000, 00, 0, 1, 2, 3, 4, 5 and 6. No. 630 (state desired size).



DePuy BONE HOOKS

Made of stainless steel with sure-grip handle and proper weight distribution for correct "feel" in use. Hooks available in four sizes, 3/8″, 1/2″, 3/4″ and 1″. No. 621 (state size desired).



DePuy FOUR-FLUTED REAMERS

Four-fluted design of these new reamers assures fast, accurate cutting action. Made of stainless steel with hand-ground cutting edges, stay sharp longer. Four sizes are available, 11/32″, 3/8″, 7/16″, 1/2″. No. 624 (state size desired).

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Since 1895

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With United States Pre-Fabricated brace parts, your Orthotist is able to fit your patients better and faster with parts that are interchangeable and easily replaceable. Specify United States pre-fabricated braces to be sure that your patients are equipped with the newest developments in orthopedic appliances.

Available in Crescent Orthopedic Steel or 24 S.T. Aluminum. French-Lock, Drop-Lock or Free-Lock Types.

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We will be pleased to send you, upon request, a complete catalog of United States orthopedic appliances. Write to

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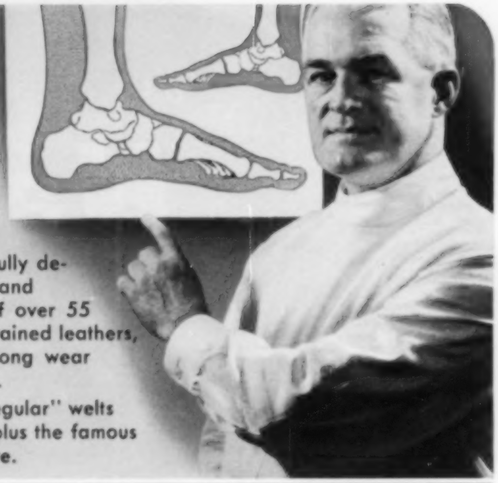
DOCTOR...

Edwards

THE SHOE FOR CHILDREN

AIDS YOUR EFFORTS



How? **Edwards** children's shoes are skillfully designed to meet your every prescription and recommendation. They are the result of over 55 years of craftsmanship. You'll find full-grained leathers, highest grade inner parts, proven fit, long wear and smart styling in every **Edwards** shoe.

A complete line—Todlins for infants, "regular" welts and cements and the "CorecTred" . . . plus the famous "Special" shoes shown here.

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for extreme cases of Pronation.

(Above style available in Oxfords)

PRONA-PEDIC

for extreme case of Supination.

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for mild cases of Supination.

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a basic shoe for corrections.

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CorecTred

shoes with special fitting features.

The construction of the above Shoes maintains the longer wedge life demanded by your prescription. Recommend and prescribe **Edwards**.

May we send you several prescription pads and the name of your nearest **Edwards** retailer?

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The Shoe for Children

Philadelphia 7
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Have you tried all three?

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Johnson & Johnson
EXTRA-FAST
EXTRA-FAST
"Specialist"

"Specialist"®

EXTRA-FAST-SETTING

For clubfoot, fore-arm and other casts where an extremely fast-setting bandage is desired.

2'' x 3 yd. 4'' x 3 yd.
3'' x 3 yd. 6'' x 3 yd.

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RESIN-PLASTER
BANDAGE
4" WIDE
Johnson & Johnson
THREE YARDS LONG

For walking-boots, long-term casts—and wherever maximal strength, minimal weight and effective moisture-resistance are essential.

3" x 3 yd.
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"Specialist"®
FAST-SETTING
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"Specialist"®

FAST-SETTING

The bandage of choice for all general cast work.

2" x 3 yd. 5" x 5 yd.
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DOCTORS rely on our ready-made and custom-made appliances to solve the problems of correction, relief, and control of growth. Modern laboratories, skilled technicians with long experience, and highest quality materials help KLEISTONE to retain the finest professional standards of workmanship. When you recommend a KLEISTONE appliance, you are recommending the very best.

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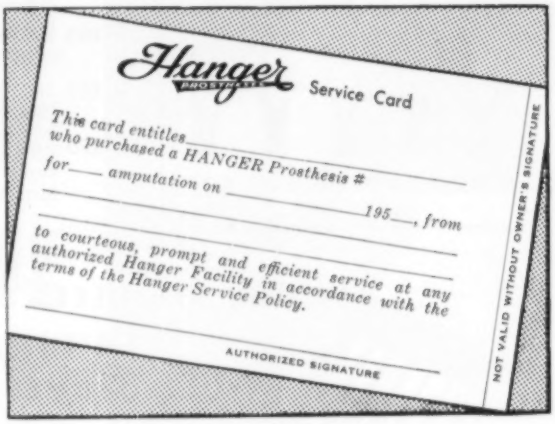

Hanger PROSTHESES Service Card

This card entitles ______________
who purchased a HANGER Prosthesis # ______
for____ amputation on ______________
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to courteous, prompt and efficient service at any authorized Hanger Facility in accordance with the terms of the Hanger Service Policy.

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A HANGER Service Card is now being issued to every new HANGER client. This card, illustrated here, bears the individual client's name, and lists on the back all authorized HANGER service facilities, located in key cities throughout the country (see list below).

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Available at authorized facilities in the following cities:

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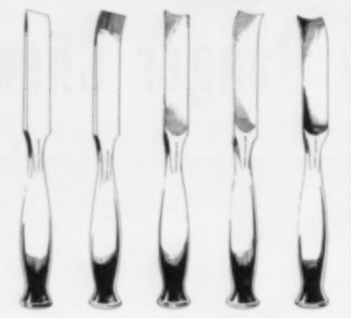
SMITH-PETERSEN OSTEOTOMES and GOUGES



0-250 0-255 0-260 0-265 0-270

0-250 SMITH-PETERSEN OSTEOTOME—straight, 8", sizes ¼", ⅜", ½", ⅝", ¾", 1" and 1¼". Stainless Steel.

0-255 SMITH-PETERSEN OSTEOTOME—curved, 8", sizes ¼", ⅜", ½", ⅝", ¾", 1" and 1¼". Stainless Steel.

0-260 SMITH-PETERSEN GOUGE—straight, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

0-265 SMITH-PETERSEN GOUGE—curved, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

0-270 SMITH-PETERSEN GOUGE—reverse curved, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

A NEW STAINLESS STEEL CASE TO HOLD SMITH-PETERSEN OSTEOTOMES and GOUGES

0-295 Open

0-295 Closed

CASE 0-295—holds seven Smith-Petersen Osteotomes.

CASE 0-296—holds seven Smith-Petersen Gouges.

CASE 0-297—holds a combination of seven Osteotomes and Gouges.

Cutting edges are protected at all times. Complete unit may be autoclaved.

Specify Width of Gouges and Osteotomes When Ordering

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Codman & Shurtleff, Inc.

MAKERS OF SURGEONS' INSTRUMENTS

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New TENSOR adjusts itself to the swelling

maintains proper support—without constriction—throughout every stage of swelling

When swelling goes up . . . Tensor elastic bandage goes with it. When swelling goes down . . . Tensor goes down, too.

Tensor is made with Live Rubber Threads which provide *lasting* elasticity. It retains its positive stretch and snap-back long after ordinary bandages are limp and lifeless.

Because of this, Tensor elastic bandage is able to give and take with the swelling. Never constricts. Never binds.

And with Tensor, doctor, you can bandage for low pressures as easily as higher pressures. Tensor elastic bandage holds whatever pressure *you* apply.

Heat won't affect its elasticity, either. Tensor can be washed and dried in automatic machines—time after time—without losing its "snap".

Shouldn't your patients have the advantages of TENSOR elastic bandage!

NEW FOR DOCTORS—Save 32% when you order in bulk

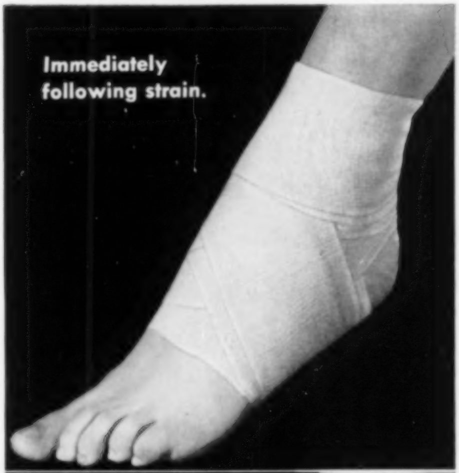
New **TENSOR®**

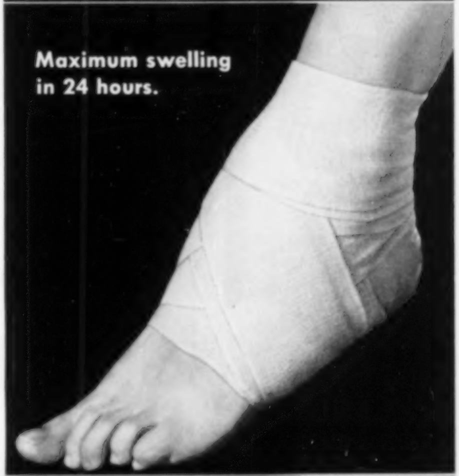
ELASTIC BANDAGE

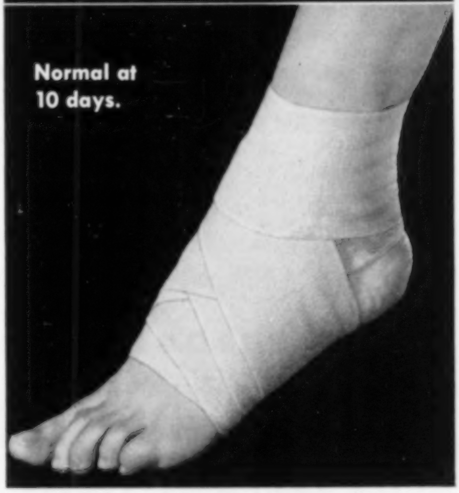
Woven with Heat-Resistant live rubber threads

BAUER & BLACK

Division of The Kendall Company
309 West Jackson Blvd., Chicago 6, Illinois



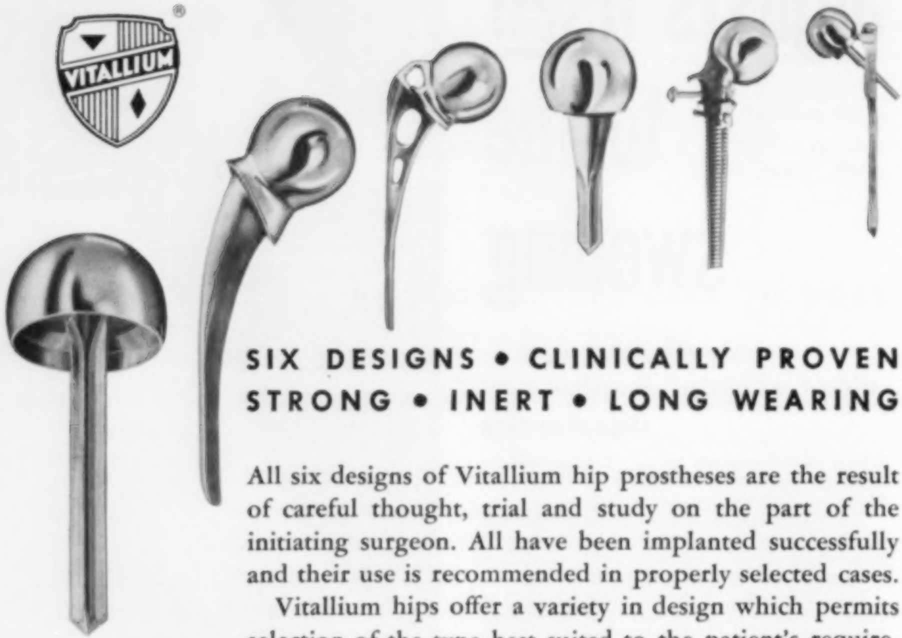




READY-MADE

Vitallium

HIP PROSTHESES



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STRONG • INERT • LONG WEARING

All six designs of Vitallium hip prostheses are the result of careful thought, trial and study on the part of the initiating surgeon. All have been implanted successfully and their use is recommended in properly selected cases.

Vitallium hips offer a variety in design which permits selection of the type best suited to the patient's requirements. They are strong, well-designed and wear-resistant. The head portions are smoothly polished and except for the Lippmann type are hollow for lightness.

Like all Vitallium appliances, the suitability of these prostheses for permanent implantation has been proven throughout 15 years of use.

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VITALLIUM HIP DESIGNS
(from left to right)

1. Modified Judet Type No. 6902
2. F. R. Thompson Type No. 6936
3. Moore Type No. 6939
4. J. E. M. Thompson Type No. 6938
5. McBride Type No. 6935
6. Lippmann Type No. 6932

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AUSTENAL LABORATORIES, INC.
SURGICAL DIVISION
224 EAST 39th STREET • NEW YORK 16, N. Y.

for patients with painful "creaky" joints

Pabirin . . . **safest of the antirheumatic salicylate-paba combinations**

For these reasons: Salicylism does not occur, even with heavy daily requirements. *Low* dosage levels produce *high* blood levels. Acetylsalicylic acid, the most effective of the salicylates, is well-tolerated. Pabirin is sodium- *and* potassium-free. It offsets salicylate depletion of vitamin C by providing a therapeutic amount of 300 mg. in the average daily dose of six capsules. **And highly effective** . . . High blood levels are promptly reached and sustained due to the mutually potentiating action of acetylsalicylic acid and PABA plus the retarding effect of PABA on salicylate excretion. Rapidly disintegrating capsules provide fast absorption and pain relief.

Pabirin is a DORSEY preparation.

Each capsule contains:

Acetylsalicylic acid	5 gr.
Para-aminobenzoic acid	5 gr.
Ascorbic acid	50 mg.

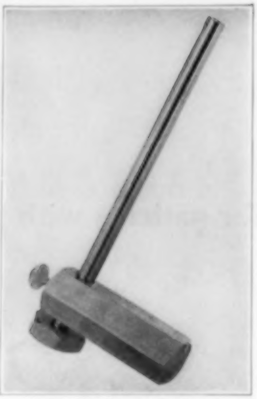
Average dose: 2 to 3 capsules 3 or 4 times daily.
Supplied: In bottles of 100, 500 and 1,000 capsules.

Pabirin®

Smith-Dorsey • Lincoln, Nebraska • A Division of The Wander Company

LOTTES TIBIAL NAIL

LOTTES TRIFLANGE TIBIAL NAIL
Tibial Nail diameters: 5/16" and 3/8"

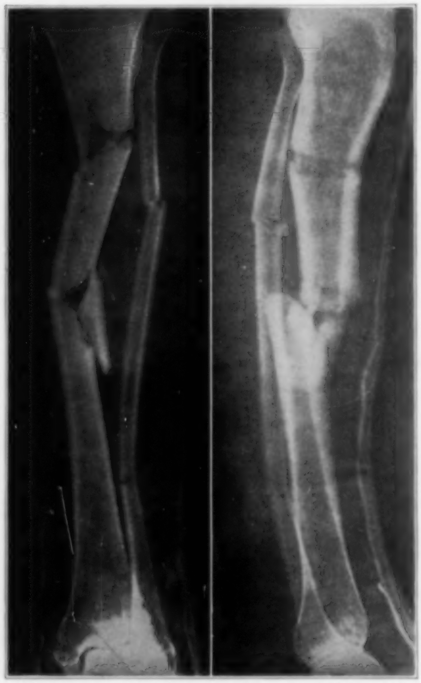


DRIVER AND EXTRACTOR

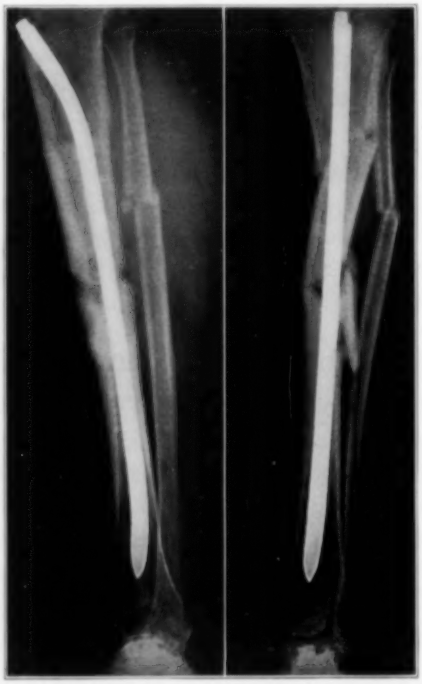
18-8 SMo Stainless Steel nail made in ½ inch lengths from 9 to 14½ inches.

The triflange nail is also available for femur, humerus, radius, and ulna.

The driver and extractor can be used with any of the triflange nails.



COMPOUND FRACTURE WHICH WAS DEBRIDED, CLOSED, AND PLACED IN CAST ON ADMISSION



RESULT THREE MONTHS AFTER PRIMARY HEALING OF WOUND AND CLOSED NAILING

For further information, please write to

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Now Available in *ALL* Price Ranges

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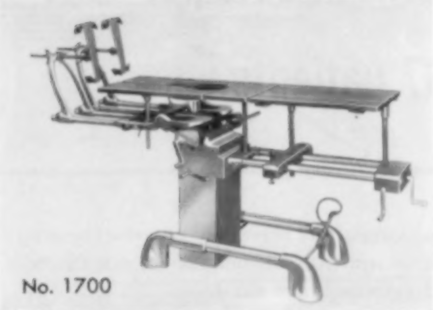
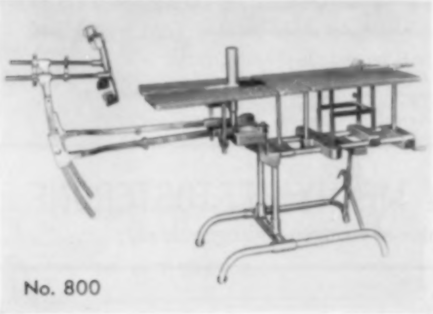


No. 1700

No. 1700 Series—For years the established leader—provides best and most complete facilities for any part of the body, including prone, lateral and perineal positioning—designed by Dr. Roger Anderson to incorporate all the sound basic principles of modern orthopedic surgery.

No. 1300 Series—Full range hydraulic lift, foot operated—true and reverse Trendelenberg—designed for hip surgery—manipulations of both upper and lower extremities, spine and neck, all about anatomical centers—all x-ray, cast and operative procedures. All three tables include built-in grounding facilities.

No. 1300



No. 800

No. 800 Series—True and reverse Trendelenberg—standard operating height—provides for spine and hip work—lower extremity facilities for abduction, extension, rotation and screw-traction about anatomical centers—accessibility for cast, x-ray and operative procedures.

Write for information and prices

the TOWER COMPANY, Inc.

SEATTLE, WASHINGTON
P. O. BOX 3181

GENEVA, ILLINOIS
(Near Chicago)

"Premarin" with Methyltestosterone effectively suppressed postpartum breast engorgement in 96.2 per cent of a series of 267 patients.[1]

"Premarin" with Methyltestosterone successfully prevents postpartum breast engorgement and suppresses lactation with virtually none of the side effects referable to either estrogen or androgen employed alone.

None of the 267 patients treated with "Premarin" with Methyltestosterone experienced nausea, vomiting, breast abscess, excessive lochia, withdrawal bleeding, or virilization.[1]

In addition, patients in this series were singularly free from the mental depression which usually appears on the fourth or fifth day of the puerperium.[1a]

Suggested Dosages: Some clinicians recommend intensive short duration therapy while others advocate lower dosage levels extended over a longer period of time. In either case, it is important to start therapy as soon as possible after delivery. Details on *short duration* therapy (one week) and *step-down* therapy (10-15 days) will be supplied on request.

1. Fiskio, P. W.: To be published; 1a. Personal communication.

"PREMARIN"® with METHYLTESTOSTERONE

ideal preparation for combined estrogen-androgen therapy

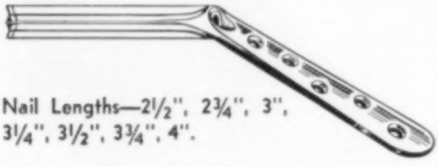
Supplied in two potencies: *Yellow* tablets (No. 879) contain 1.25 mg. of conjugated estrogens (equine) and 10 mg. of methyltestosterone; *red* tablets (No. 878) contain 0.625 mg. and 5 mg. respectively. Available in bottles of 100 and 1,000.

Ayerst Laboratories • New York, N. Y. • Montreal, Canada

5527

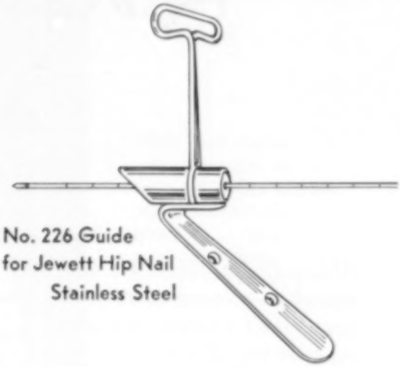
Jewett ONE-PIECE NAIL . . . AND COMPLETE SET OF INSTRUMENTS.

No. 224J—Jewett One-Piece Hip Nail. Drop forged SMO Stainless Steel—Cannulated.

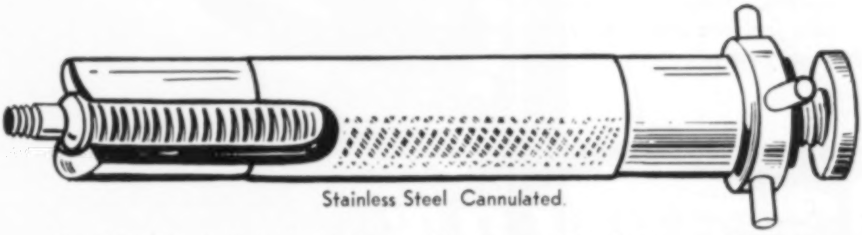


Nail Lengths—2½", 2¾", 3", 3¼", 3½", 3¾", 4".

Plate Lengths—4", 5", 6".

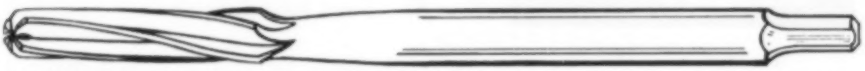


No. 226 Guide for Jewett Hip Nail Stainless Steel

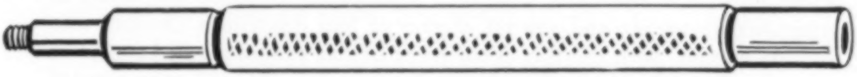


Stainless Steel Cannulated.

No. 208J Extractor-Impactor for Jewett One Piece and Smith Petersen Hip Nails.



No. W402J Henderson Cortex Reamer. Cannulated. Fits Jacobs Chuck. Stainless Steel.



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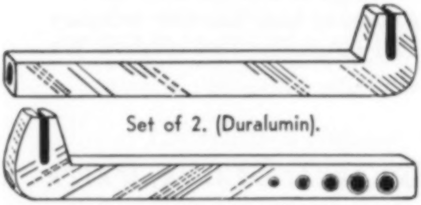

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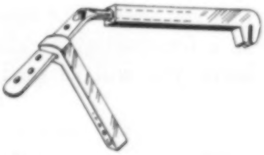

Illustration shows one of many uses of plate bending irons.

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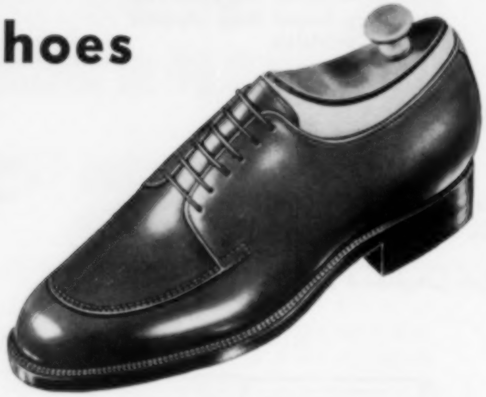

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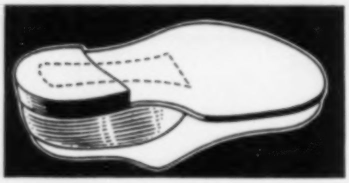

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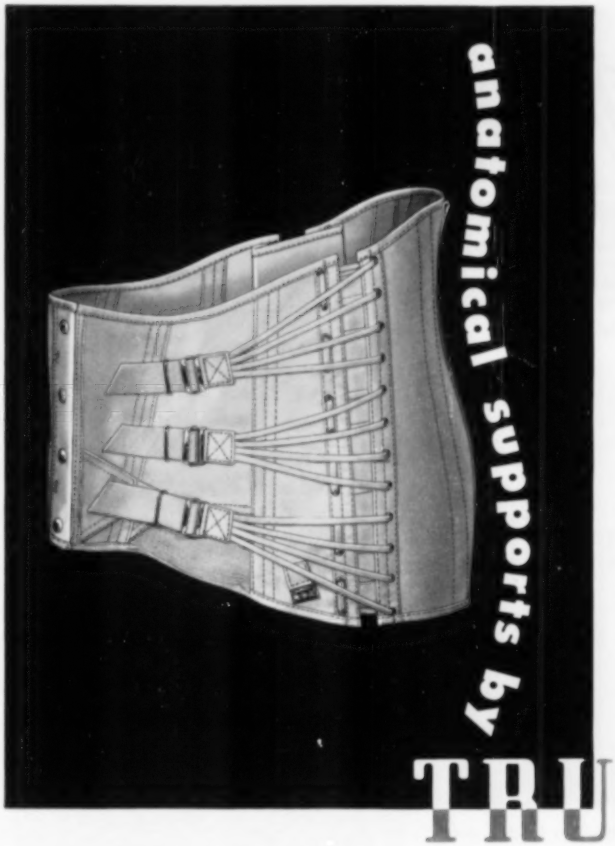

THREE pull straps control traction in model 430-EHS lumbosacral support pictured . . . two semi-rigid steels. WRITE for "Truform Red Book," the fully illustrated reference catalog of Surgical Supports and Elastic Hosiery.

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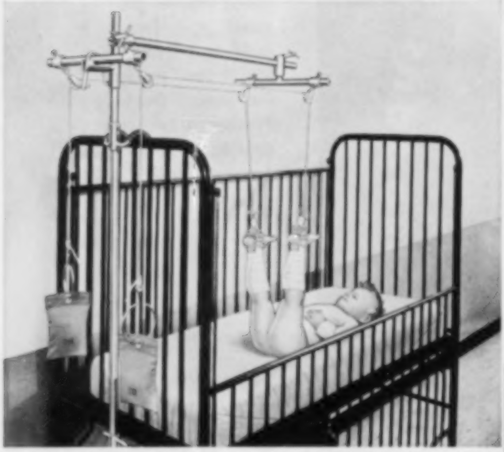

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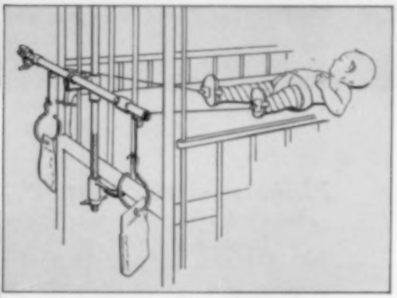

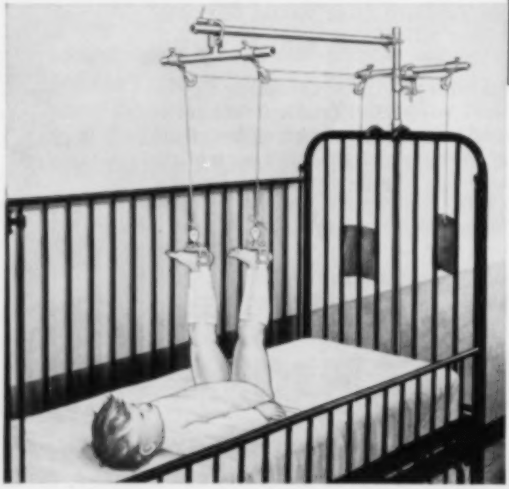

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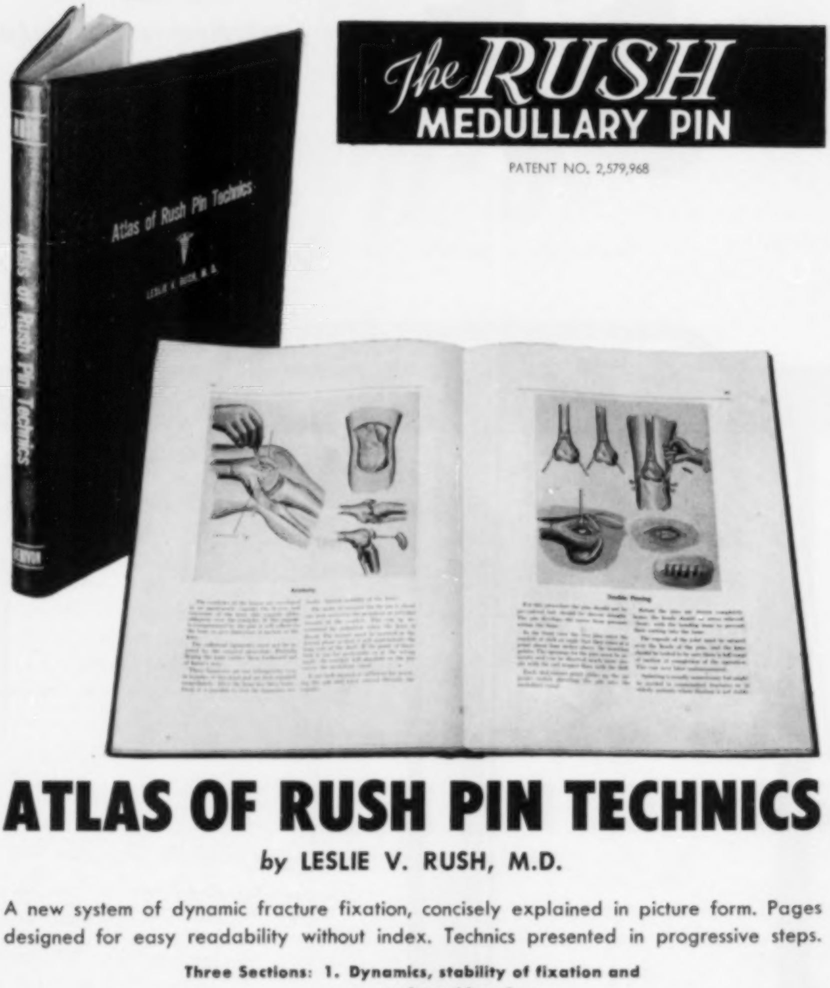
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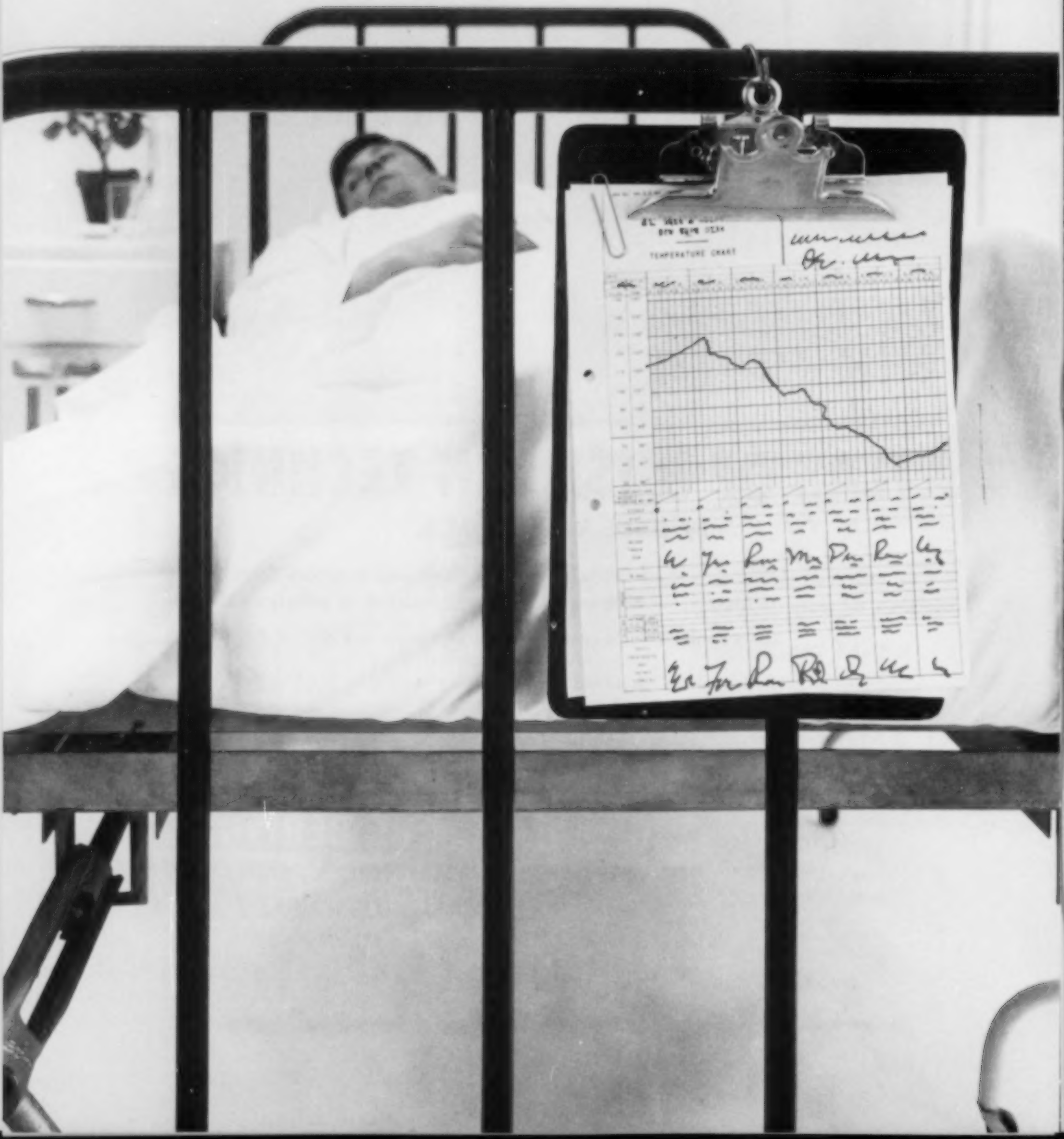
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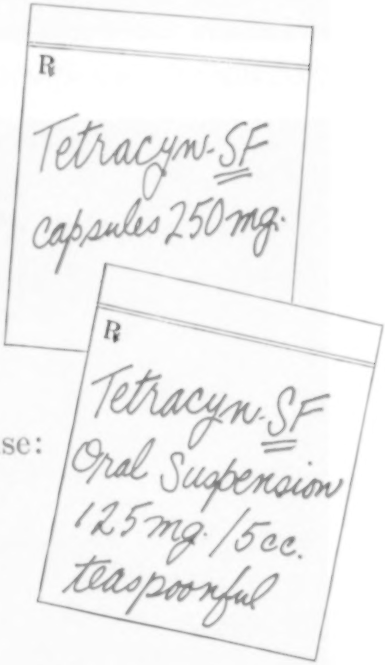

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1. Pollack, H., and Halpern, S. L.: Therapeutic Nutrition, Prepared in Collaboration with the Committee on Therapeutic Nutrition, Food and Nutrition Board, National Research Council, Washington, D. C., 1952.
2. Martí-Ibáñez, F.: Antibiotic Med. *1*:247 (May) 1955.
3. Dumas, K. J.; Carlozzi, M., and Wright, W. A.: Antibiotic Med. *1*:296 (May) 1955.

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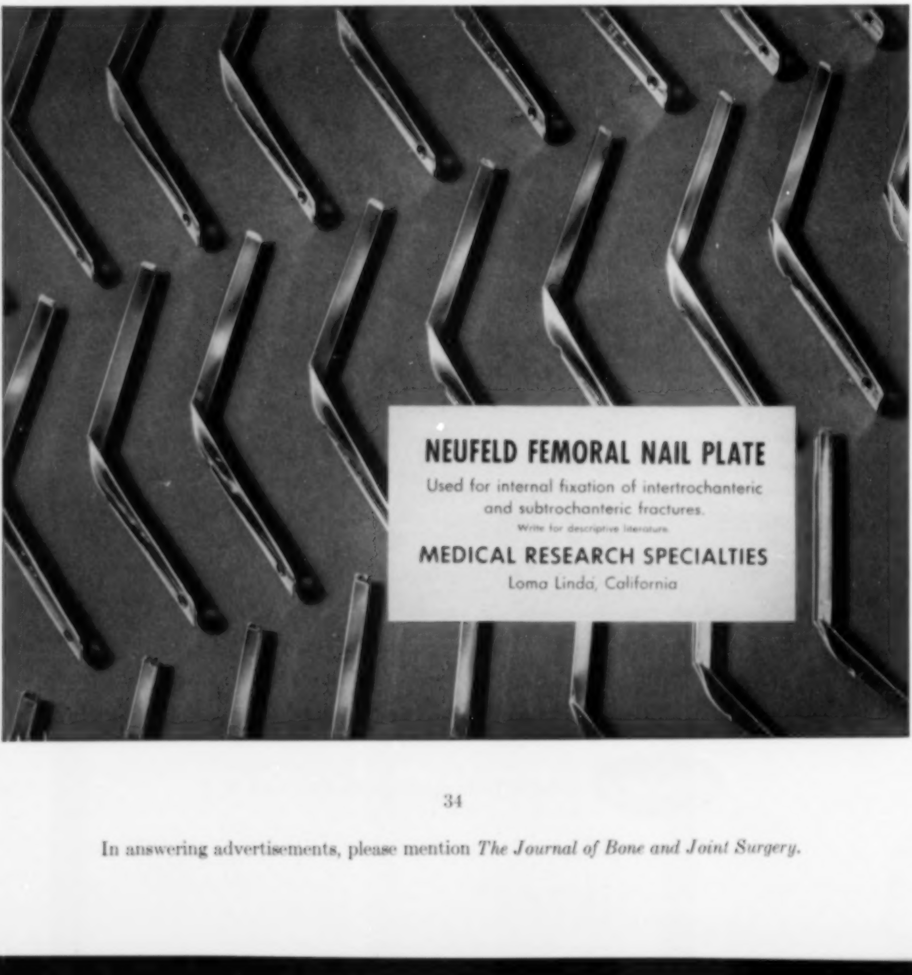

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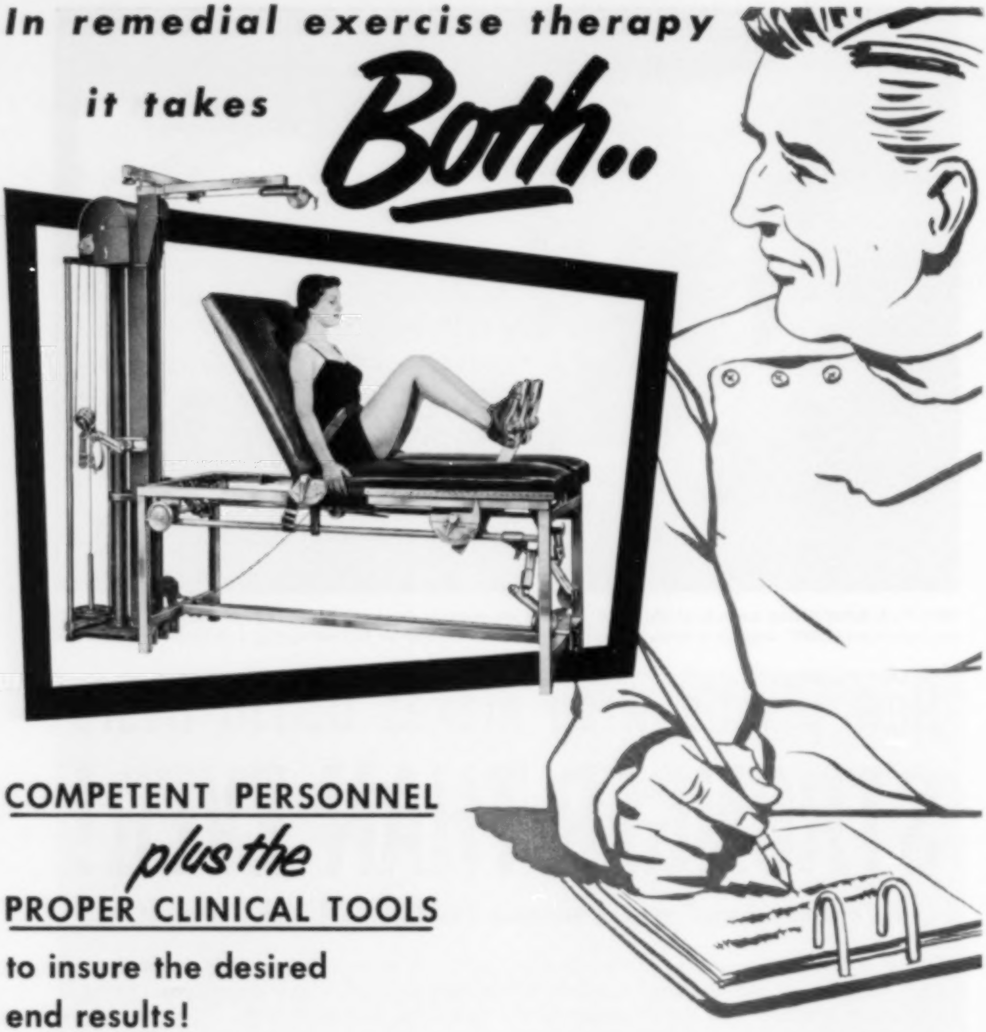

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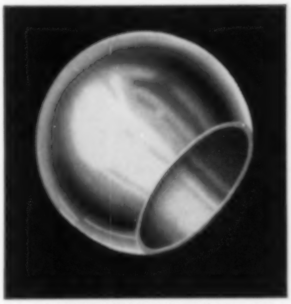

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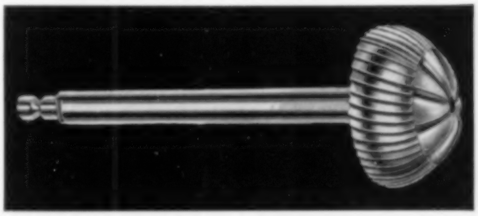

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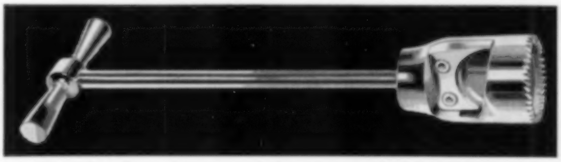

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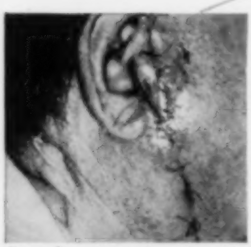

Face laceration dressed with Aeroplast healed in four days.[2]

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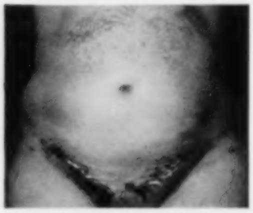
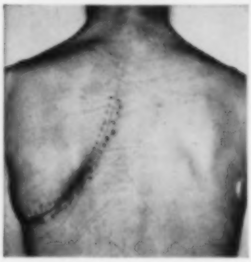


Bilateral inguinal hernia incisions protected by Aeroplast 4th post-operative day.[1]

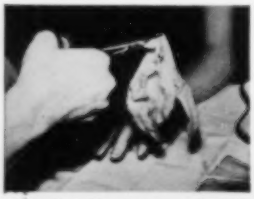
Rigler and Adams[1] dressed 110 operative wounds (including thoracotomies, laparotomies, inguinal hernias and miscellaneous lesions) with Aeroplast. "A single application sufficed in all but fifteen cases. No instances of systemic or clear-cut reactions were observed. Satisfactory results, with no evidence of erythema, infection, or necrosis were obtained in the majority of cases."



Thoracotomy wound completely healed 13 days after operation and dressing with Aeroplast.[1]

In 39 miscellaneous wounds dressed with Aeroplast (including appendectomies, open reduction of fractures, skin graft donor sites, lacerations, excoriation), Choy[2] reports infection in only one case, which promptly cleared with redressing, and uneventful healing in all others.

1. Rigler, S. P. and Adams, W. E.: Experience with a new sprayable plastic as a dressing for operative wounds, Surg. 36:792 (Oct.) 1954. (University of Chicago Clinics, Chicago, Surgical Service).
2. Choy, D. S. J.: Clinical trials of a new plastic dressing for burns and surgical wounds, Arch. Surg. 68:33 (Jan.) 1954. (Bellevue Hospital, New York, Third Surgical Division—Dr. John Mulholland, chief).



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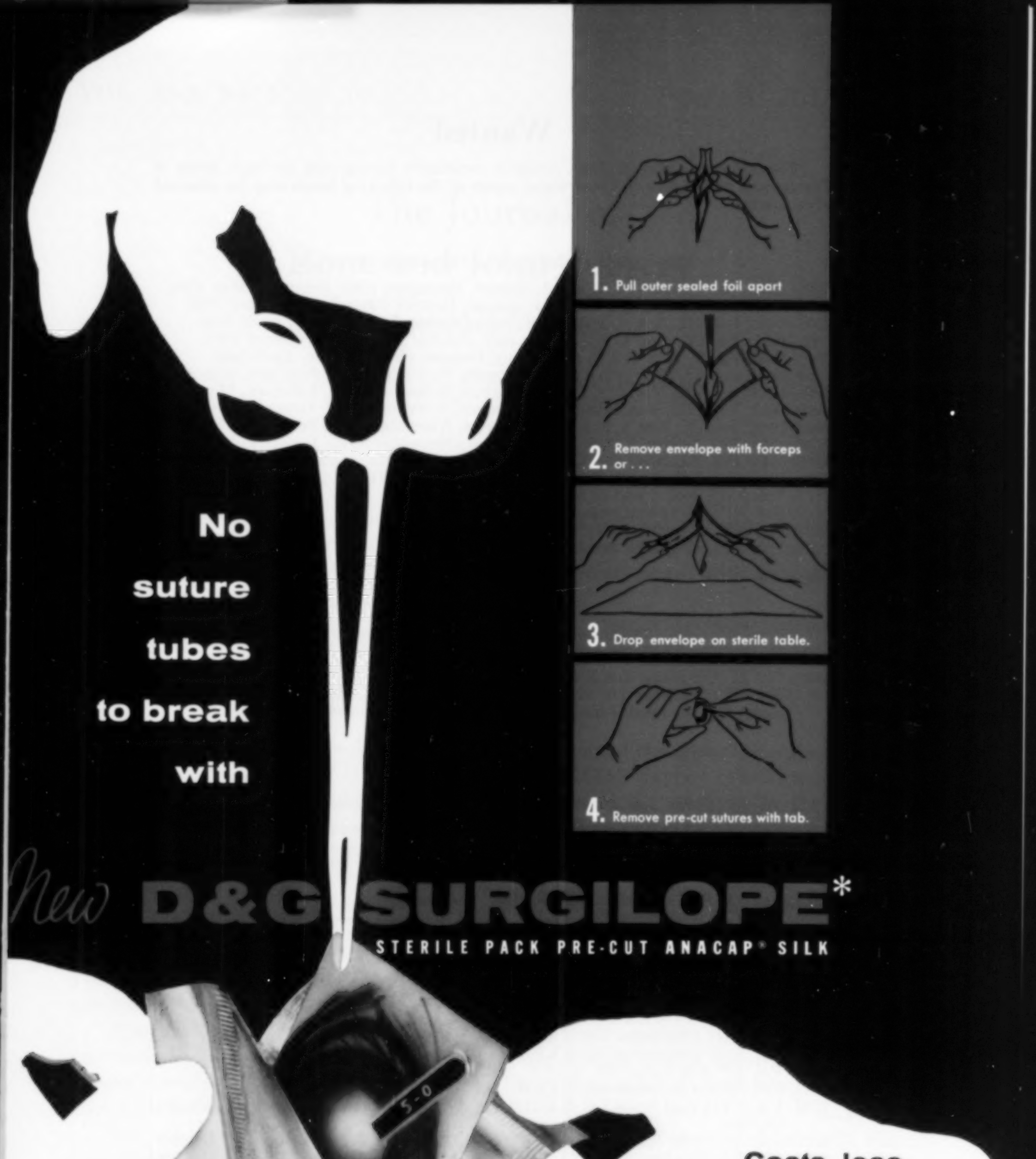

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VOL. 37-A, No. 4 JULY 1955

The Journal of Bone and Joint Surgery

American Volume

A STUDY OF THE ARTERIAL VASCULARIZATION OF THE FEMORAL NECK IN THE ADULT

BY DR. J. JUDET, DR. R. JUDET, DR. J. LAGRANGE, AND DR. J. DUNOYER,
PARIS, FRANCE

In recent years, arthroplastic surgery of the hip has assumed considerable importance. The anatomy of the femoral neck supporting the prosthesis has, therefore, become quite important to surgeons who had, until then, been concerned mainly with the pathological alterations of the femoral head.

The present work aims to give an accurate description of the intra-osseous arterial system of the femoral neck and to examine the effects on that system of the various operations performed on the hip.

HISTORICAL REVIEW

Two types of study have dealt with the blood supply of the upper femoral epiphysis. Anatomists such as Hunter (1796), Astley Cooper (1824), Sappey (1869), and Poirier (1899), have described the different vascular systems of the epiphysis in their extra-osseous course. Other authors, going still further, have described more precisely the distribution and the relative importance of the various groups of arteries and have tried to describe systematically their intra-osseous distribution.

Kolodny, in 1925, and Wolcott, in 1943, investigated the vascular supply of the ligamentum teres.

Tucker, in 1949, using a technique of injection similar to that later described by Trueta and Harrison, examined the vascularization of the femoral head and gave an accurate description of the groups of arteries of the head and of their anastomoses.

Cheynel, in 1954, reviewed the subject, but the most important study on this matter was made by Trueta and Harrison in 1953; these authors clearly described the intra-osseous vascular system of the femoral head. They demonstrated accurately its connections with the vascular meshwork in the neck which they described for the first time.

Our study will confirm the general conclusions drawn by these authors, with the exception of some differences which we shall point out in the course of this paper.

MATERIAL AND METHOD

Our study of the intra-osseous vascularization of the femoral neck was made according to the technique perfected by Trueta and Harrison. One of us (J. L.) visited the Wingfield-Morris Orthopaedic Hospital in Oxford in 1952, in order to study this method. Only minor modifications were made in this technique.

The material used for all injections was barium sulphate in aqueous suspension. We experimented with several mixtures in order to obtain a suspension as stable as possible, of which the particles are as small and as homogeneous as possible so that they can penetrate the intra-osseous capillaries. The product which gave the best results is British (micropaque); the size of the particles is about 0.5 micron.

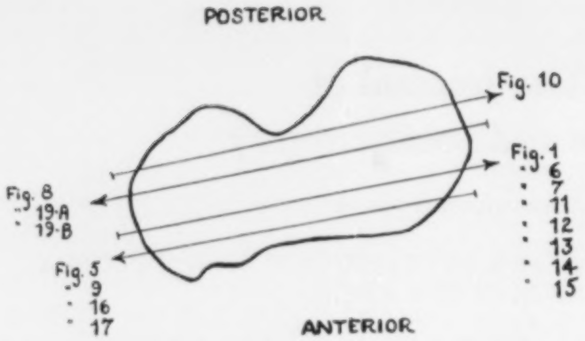

Fig. A

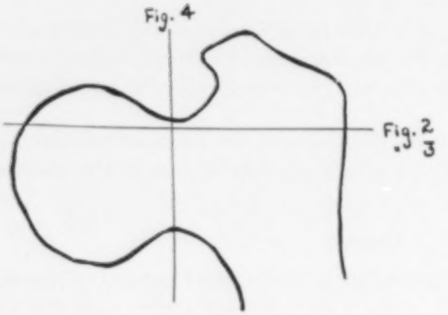

Fig. B

Figs. A and B: Key drawings indicating the level of the sections shown in Figures 1 through 17, 19-A, and 19-B.

The product is injected by means of an instrument effecting a permanent known pressure during the necessary time and a variation of this pressure at will during the injection.* In general, we have used a pressure rising progressively to 600 millimeters of mercury maintained for five to ten minutes.

In the beginning, we injected large specimens taken from cadavera less than twenty-four hours after death, but it soon seemed advisable to make the injection directly into the cadaver itself and then to excise the specimen we wanted to investigate.

In every case the injection was made into the external iliac artery. A tourniquet placed in mid-thigh prevented the barium sulphate from spreading into the soft tissues of the lower limb.

After being injected, the bone specimen was dissected, sawed into slices about half a centimeter thick, fixed in formaldehyde, and then decalcified in a 6 per cent. solution of sulphuric acid. After decalcification, roentgenograms of the slices of bone were made by means of a lamp tube giving soft rays (of the type used in crystallography); small-grain films, allowing a sizable enlargement of the pictures, were used.

Before an experiment is undertaken, the method must be understood and its limitations must be known.

First, we tried to conform as closely as possible to normal physiological conditions; to do so, we injected under the same pressure as the average arterial pressure. In addition, we experimented with different viscosities of the barium suspension until we obtained a viscosity similar to blood.

The results were not satisfactory, first, because the opacity to x-rays of the suspension in the intra-osseous arterioles was insufficient for obtaining good pictures, and, second, because the material injected ran into the venous capillaries and then into the veins, therefore making it impossible to read the pictures. By increasing the viscosity of the suspension (that is, by increasing its barium content), we were able to obtain sufficient filling of the intra-osseous arterioles and even of the large arterial capillaries, as well as a proper opacity to x-rays, without taking the risk of injecting the venous meshwork at the same time. However, in order to accomplish this, we had to increase the pressure in the injection system considerably, to three or four times the normal arterial pressure. In spite of this, we never saw rupture of an extra-osseous or intra-osseous artery, except for the sinusoids of the hemopoietic marrow.

It is evident, therefore, that it is possible to select the type of vessel to be studied according to the variations of both factors, the viscosity of the suspension and the pressure of the injection.

* We are indebted to Mr. Vladimir Traoubenberg for his ingenuity in making the instrument.

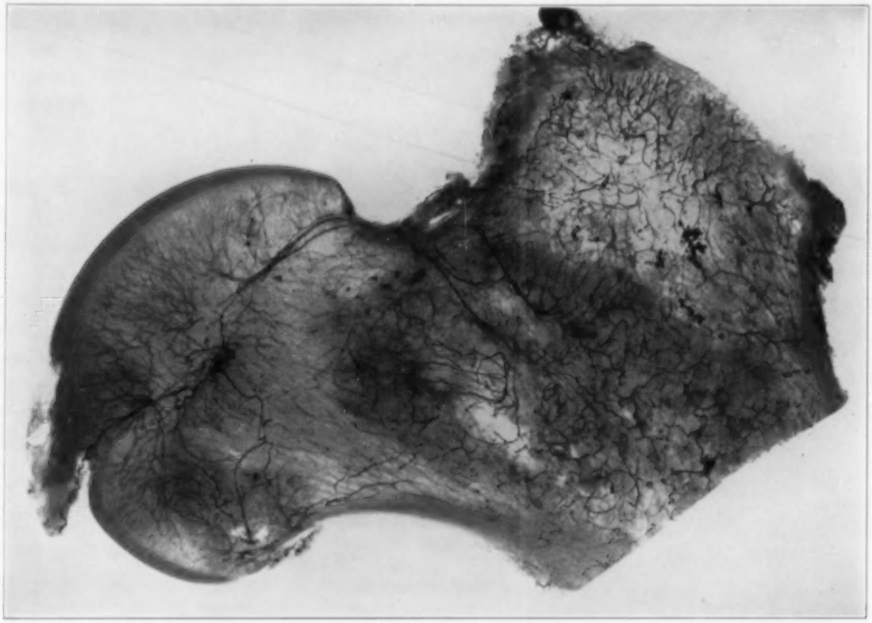

FIG. 1

General view of the intra-osseous circulation in the upper end of the femur.

However careful we were, some of our results were not conclusive. We cannot explain this. The vascular condition itself might be the explanation; therefore, a considerable number of preparations are necessary to give significant conclusions. For this reason we injected both hips of the same cadaver whenever possible, for accurate comparison. Finally, as we have applied it, this method of vascular injection is predominantly a method of anatomical investigation. From the mere existence of vessels we cannot draw conclusions concerning their functional value.

The conclusions of this study are based on the examination of sixty-five successful injections of the femoral neck. We injected only hips of adults aged twenty-eight to eighty-three.

NORMAL ARTERIAL PATTERN IN THE FEMORAL NECK OF THE ADULT

For the purpose of this study we have followed the anatomical definition of the femoral neck,—that is, we take it as limited laterally by the intertrochanteric line and medially by the cartilage covering the femoral head.

Several systems bring the blood supply to the femoral neck.

1. *Superior Group of Arteries*

This group (Figs. 1, 2, and 3) is the most important because of the number and size of its vessels. They enter the bone through the superior rim of the neck.

They originate from the medial femoral circumflex artery or from its anastomosis with the lateral femoral circumflex artery, the obturator artery, and the inferior gluteal artery. The anastomosis takes place next to the trochanteric fossa.

These vessels run on the outer surface of the articular capsule, along its femoral attachment.

The three or four arteries which supply both the neck and the head run directly inward, then slip under the synovial membrane which covers the superior rim of the neck,

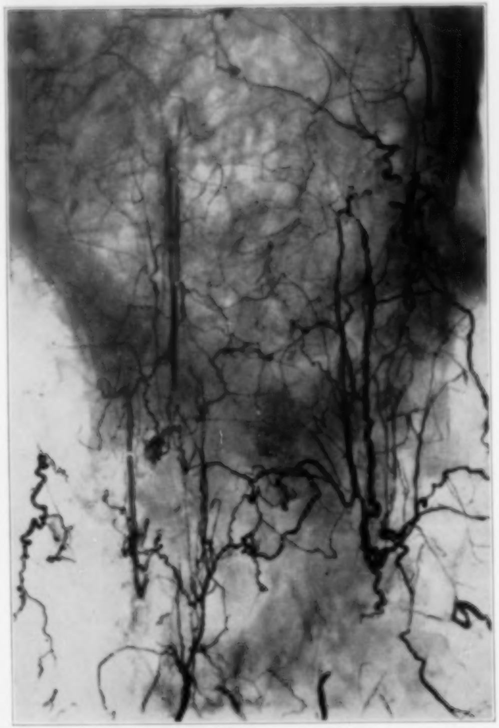

FIG. 2

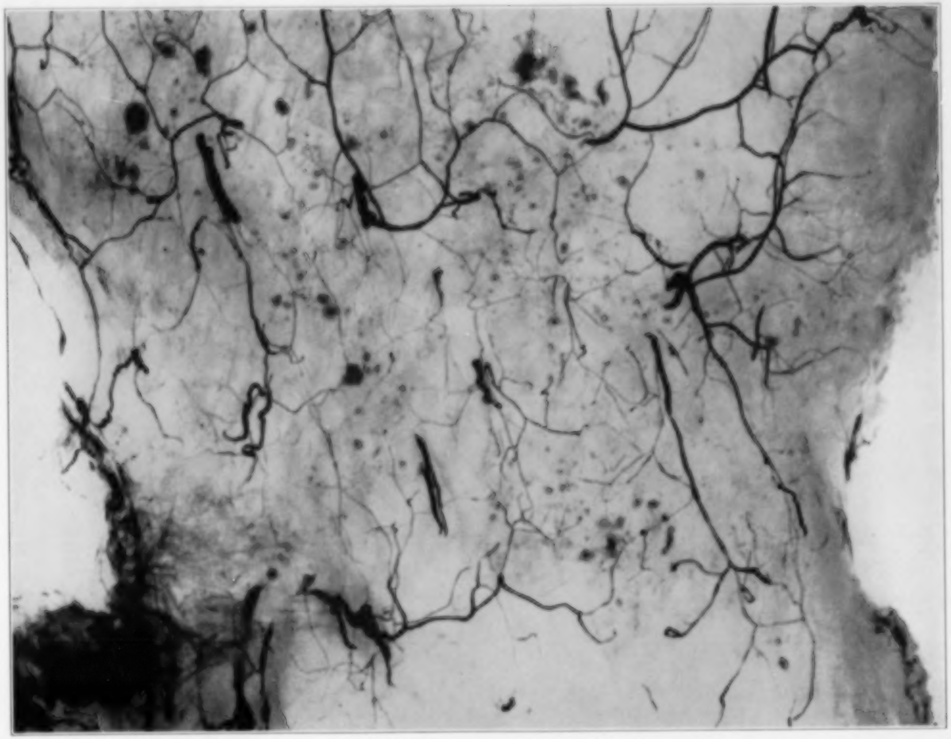

FIG. 3

Fig. 2: Horizontal slice from the superior border, along which the arterioles course before they penetrate the bone.
Fig. 3: Enlargement of the superior border of the neck in the area where the arterioles penetrate the bone, coursing toward the neck or the head.

and course along the bone. Just before reaching the cartilaginous rim of the femoral head, these arteries penetrate the bone and supply two thirds or three quarters of the head. (These are Trueta and Harrison's "lateral epiphyseal arteries".)

Each of these arteries in its course gives off one or two cervical collateral branches. Together the six to eight arterioles form the superior group of arteries of the neck (Figs. 4 and 5).

The origins of these cervical branches are many, but two of them predominate. In some cases, these cervical branches start medially, a few millimeters from the femoral head, the cervicocapital arteries dividing just before they reach the cartilage of the head (Fig. 6) in 20 per cent. of cases. In other cases, the cervical branches start earlier laterally, running along with the capital arteries for a few millimeters, and penetrate the neck, near the line of the lateral capsular insertion. Sometimes, on entering the bone, these arteries wind into a few spirals (Figs. 7 and 8).

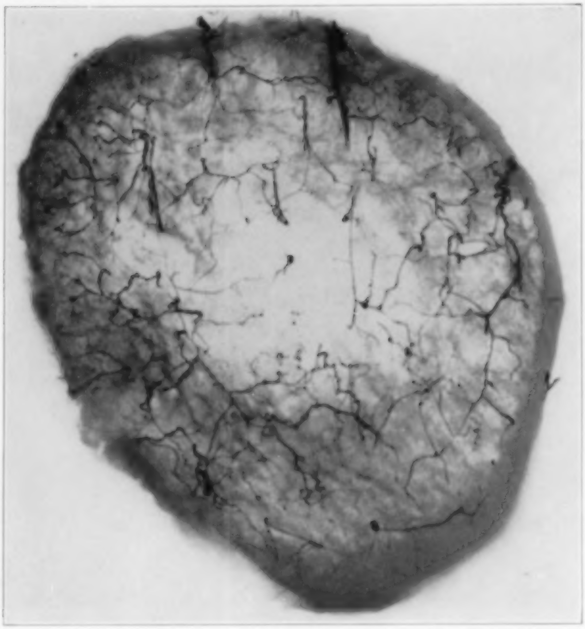

FIG. 4

A slice of the neck perpendicular to the long axis.

One or two arterial branches can often be seen penetrating the bone alongside the

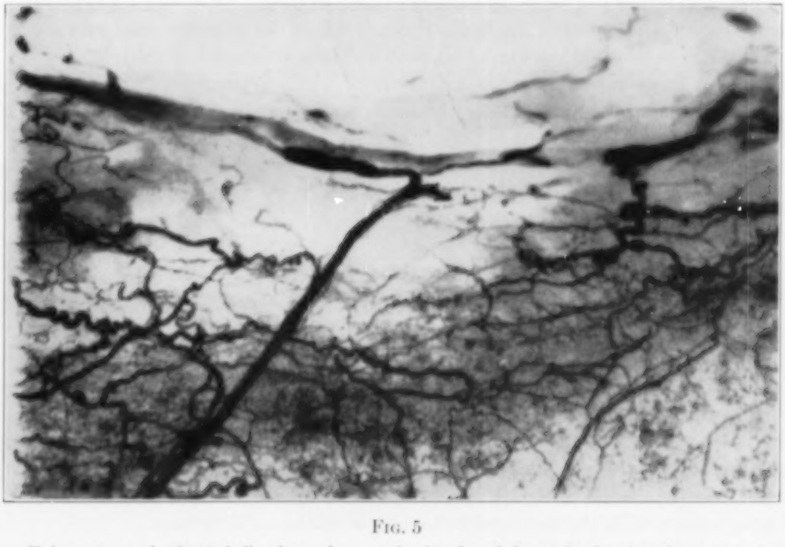

FIG. 5

Enlargement of a frontal slice from the superior border of the neck, showing the origin of an arteriole of the superior group.

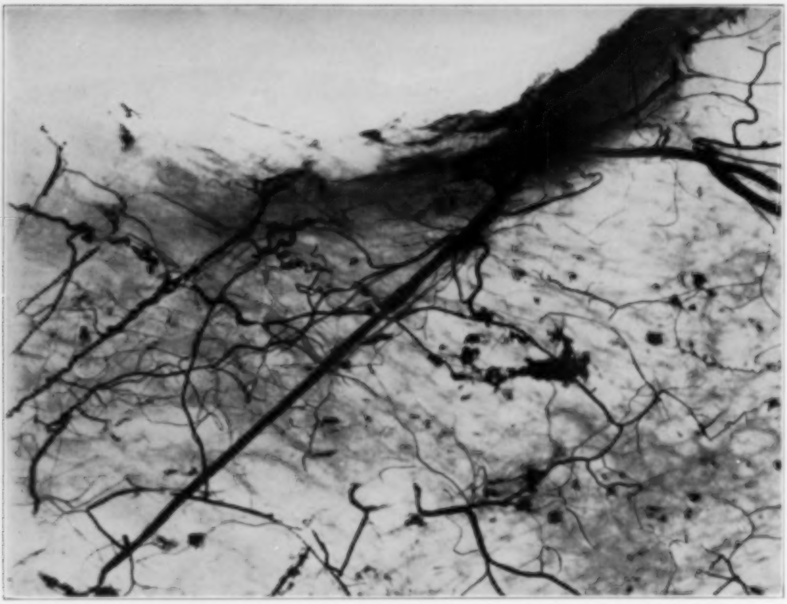

FIG. 6

Enlargement of a frontal slice. In this case, the arteries supplying the neck originate quite far medially, near the cartilaginous covering of the head.

upper trochanter; they run straight down to the center of the diaphyseal canal, supplying the most distal part of the neck, regardless of the variations of the superior group of arteries.

We must point out the great number and the regularity of anastomoses among all the arteries of the superior group. Many small vessels course from one to the other; they run either outside or inside the bone, but always close to their origin. We observed in all the specimens studied that, within the neck, the arteries of the superior group have a regular course; they run straight downward and outward to the femoral diaphysis.

When they reach about the middle of the neck, they divide, branching in all directions inside the cancellous bone; these terminal branches go as far as the cortex of the inferior rim of the neck, which they help to supply.

One or several of these terminal branches run inward, describing almost a right angle, and course toward the medial vessels of the inferior group with which they freely anastomose (Figs. 1 through 8).

2. *Inferior Group of Arteries*

Two groups of inferior arteries are given off by the medial circumflex artery which follows the lateral capsular insertion.

From this artery two, three, or four vessels arise which run inward. In the first part of their course, they are generally in the folds of the capsule, and then run between the synovial membrane and the bone.

The vessels of the lateral inferior group are rather small; this group is formed by two or three small collateral branches starting in the folds of the capsule and penetrating the inferior cortex of the neck, which is very thick at this point. They supply it, pass through it, and anastomose with the terminal branches of the superior group.

The vessels of the medial inferior group are more important. These arteries penetrate the bone very close to the cartilaginous border of the femoral head. They run straight

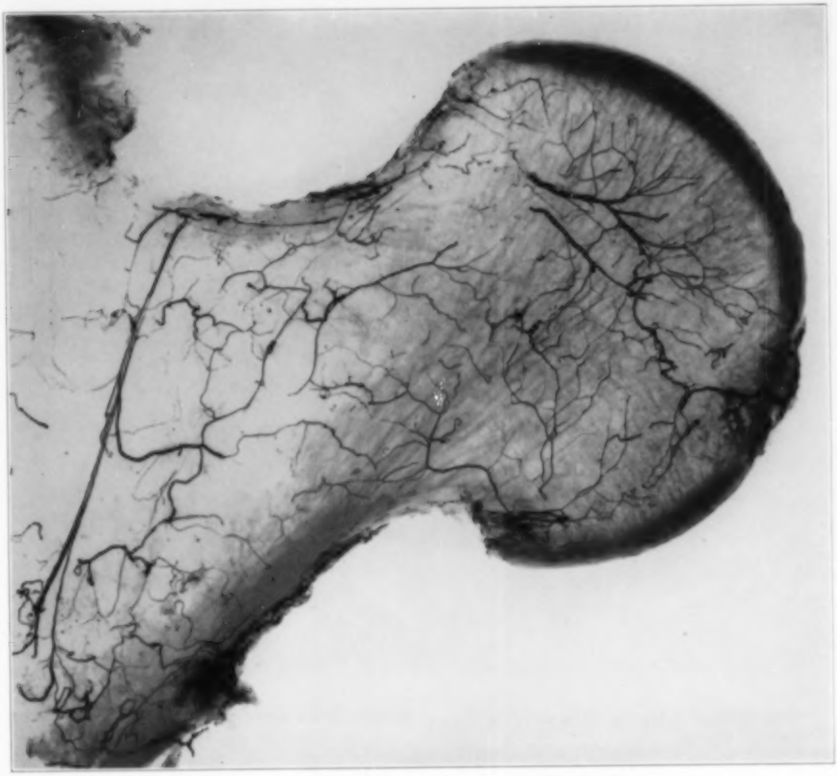

FIG. 7

Frontal slice. The arteries supplying the neck originate far laterally, near the trochanter. Note the anastomoses with the lateral inferior group.

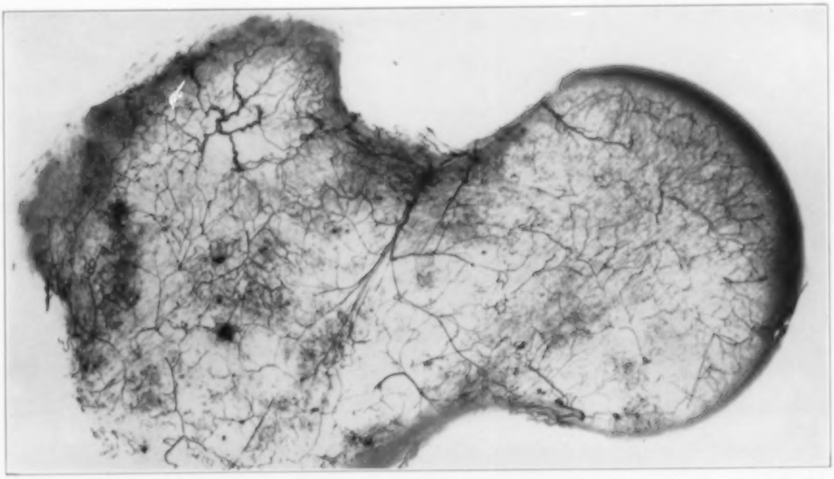

FIG. 8

Frontal slice showing a frequently occurring pattern of the superior arterial groups.

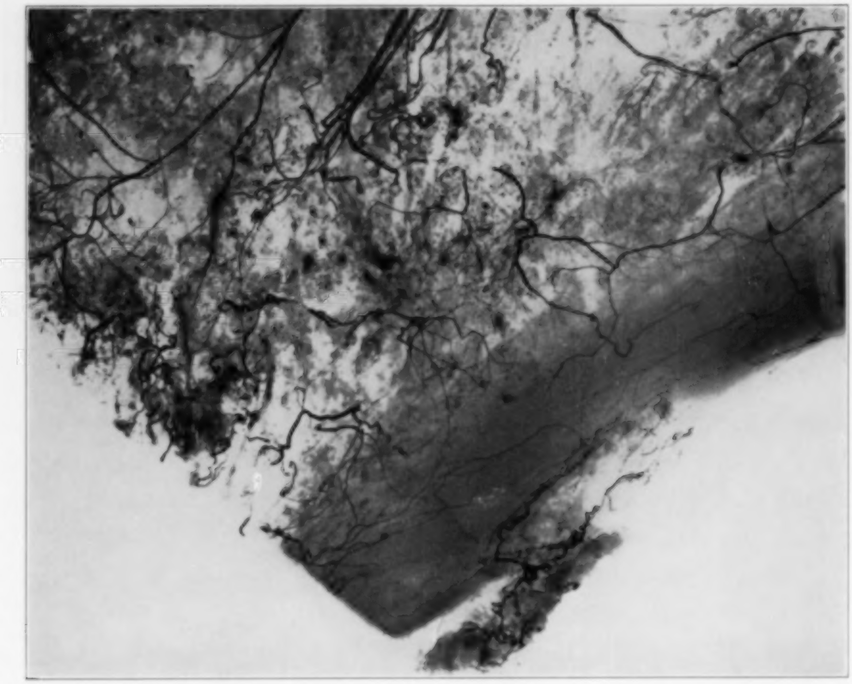

FIG. 9

Enlargement of a frontal slice, showing the medial inferior group and the terminal branches of the superior group.

upward and soon spread out into many terminal branches which form two groups: one coursing inward and upward and supplying the inferior third or quarter of the head;

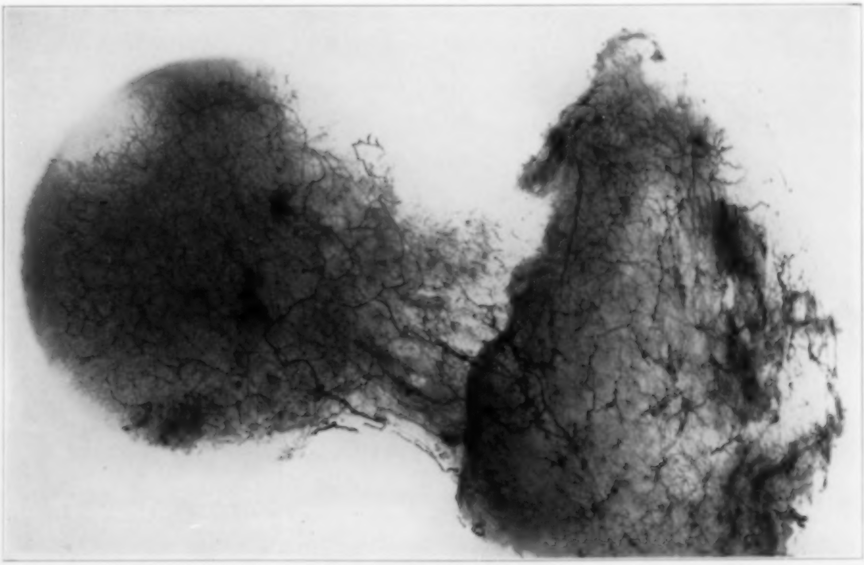

FIG. 10

Frontal slice, demonstrating the arterial pattern of the posterior aspect of the neck.

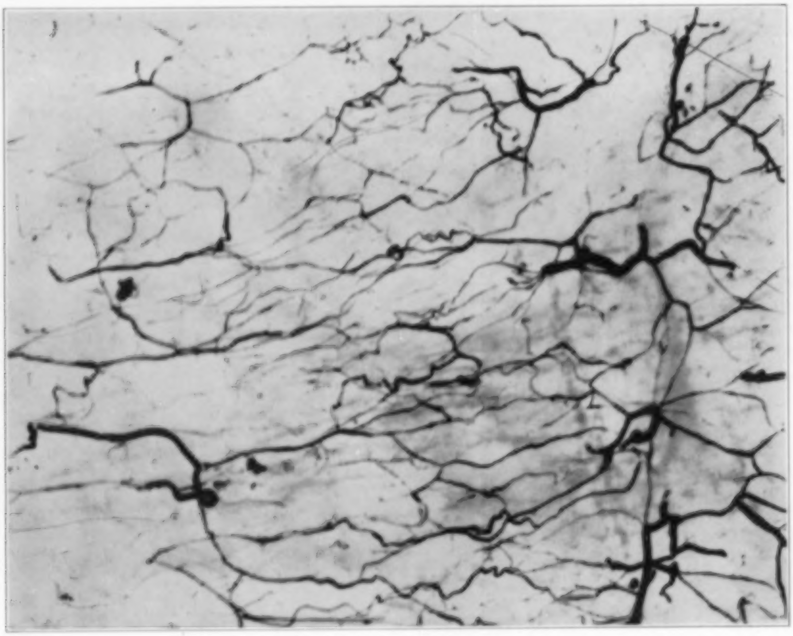

FIG. 11

Enlargement of the area of anastomoses between the vascular systems of the neck and the head.

the other passing inward, forming a hair-pin course which contributes to the blood supply of the inferior and medial part of the neck. This group of arteries anastomose freely with those from the superior group and from the lateral inferior group.

3. *Arteries of the Anterior and Posterior Aspects of the Neck*

These arteries differ from the groups of arteries described above, because their course is not so regular and because, for the most part, they do not supply the cancellous portion of the bone, but end in the cortex, forming only a thicker peripheral meshwork.

This group consists of fine arterioles given off by the lateral and medial circumflex arteries. They originate from these arteries between the synovial membrane and the bone. From the base of the neck, they run directly toward the head. Their pattern is quite regular at the posterior aspect of the neck in its lower half.

They are not so numerous on the anterior aspect; frequently only a fine arteriole is found slanting upward and inward (Nussbaum's anterior branch). There are many anastomoses among all these vessels.

ANASTOMOSES

As has been mentioned, there are numerous anastomoses among the various groups of arteries of the neck. Each of the groups also anastomoses with the adjacent systems. The superior and medial inferior groups anastomose with the arteries of the femoral head. A series of more or less parallel anastomoses can always be seen (Fig. 11) at the site of the former epiphyseal plate. Trueta and Harrison have mentioned this, and we have never failed to find it.

The superior group is also connected with the trochanteric vascular system.

The trochanter has its own vascular group. Numerous small arterioles penetrate the cortex, where they ramify without reaching the cancellous bone. Also, two or three large

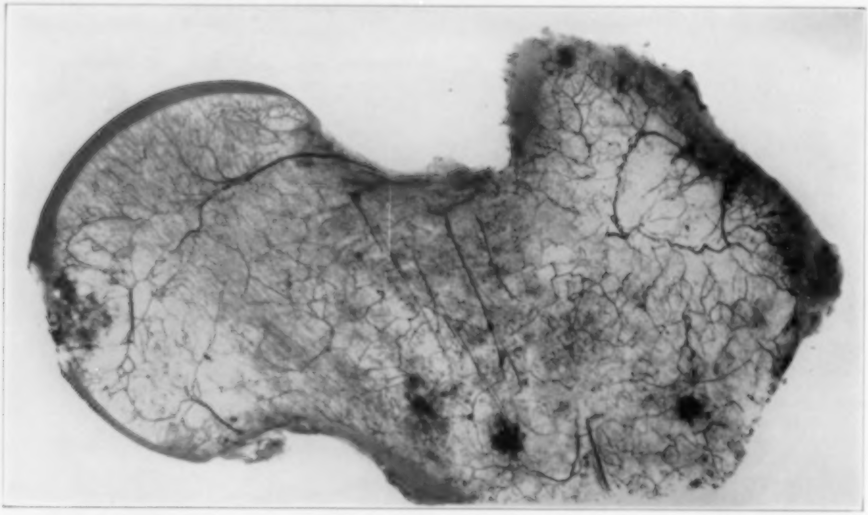

FIG. 12

Frontal slice. Note the pattern of the trochanteric system and its anastomoses with the cervical arteries.

arterial branches penetrating the bone near the top of the lateral aspect run deep into the center of the cancellous area.

These arteries ramify in stellate fashion, issuing in all directions branches which supply the cancellous area and end in numerous vessels supplying the deep layer of the cortex.

The arteries of the superior group of the neck anastomose with those of the trochanteric area, following a fairly definite line from the trochanteric fossa and slanting downward and outward to the subtrochanteric crest.

Finally, the terminal branches from the superior group of arteries of the neck, some of which sometimes penetrate as far as the upper part of the diaphysis, anastomose completely with the diaphyseal vessels.

In a detailed analysis of their findings concerning the blood supply of the femoral head, Trueta and Harrison have described two different types of vascularization of the marrow related to the two types of marrow: hemopoietic and fat. In the red hemopoietic marrow, the arterioles terminate at wide thin-walled sinusoids which gather to form the lobules of the marrow. In the fat marrow they found capillaries similar to those of other tissues draining out into the veins.

We have found the same arrangement in the femoral neck (Fig. 13).

Comment

Several conclusions may be drawn from this descriptive study of the vascularization of the femoral neck: Almost all of the cancellous area of the neck is irrigated by the superior group of arteries alone. On the other hand, this group supplies only a very limited area of the cortex, except for the inferior cortex which is supplied by all three of the groups of arteries of the neck.

The main groups feeding the head and the neck have a common origin.

There is an abundance of extra-osseous and intra-osseous anastomoses among the various groups of the neck.

If we compare the actual arrangement of the vessels as we usually find it with the classical description of the pattern of the osseous trabeculae, it will be seen that the

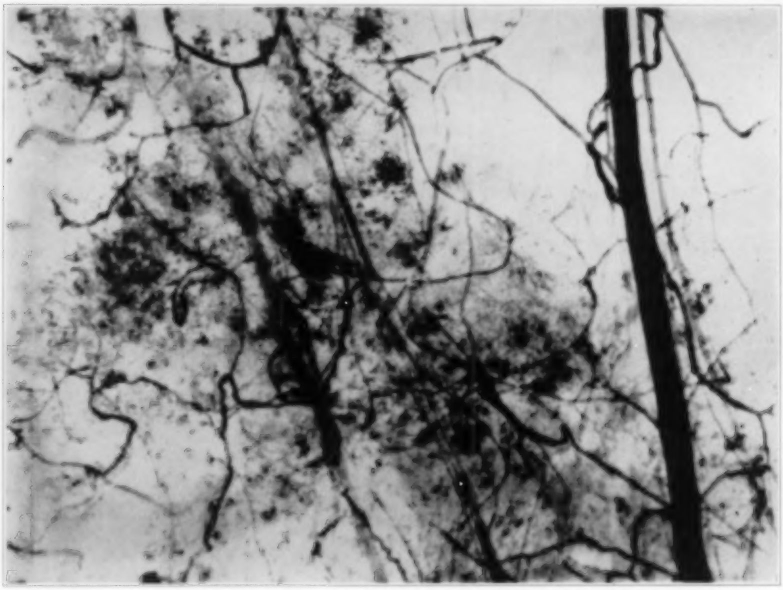

FIG. 13

Demonstrating the sinusoids of the hemopoietic marrow.

arterial distribution is not influenced by the pattern of the osseous trabeculae, except at the level of the remnants of the trochanteric and cervicocapital growth plates.

VARIATIONS OF THE ARTERIAL CIRCULATION IN THE NECK

The ages of the subjects injected ranged from twenty-eight to eighty-three. No vascular change was noticed which could be correlated with age. Contrary to the statements of many authors, there is no reason why the femoral neck, in old age, should not keep a normal blood supply, since the size, the pattern, and the anastomoses of the vessels are the same, regardless of whether the subject is thirty or eighty years old.

However, some specimens showed a greater degree of vascularity than others. This is due to the greater or lesser amount of red marrow in the neck. As has been demonstrated, the hemopoietic marrow abounds in sinusoids visible on preparations; the fat marrow, on the other hand, has few vessels.

We were not able to establish any relation between the age of the subject and the relative predominance of the hemopoietic and fat areas in the marrow. In most cases, the central area of the neck, around the vessels of the main groups of arteries, contains red marrow prolonging the diaphyseal marrow. An isolated spot of red marrow is frequently found next to the inferior pole of the head. On the other hand, these are never found in the trochanter.

In some specimens, almost the whole of the epiphysis contained only fat marrow. In two specimens, however, the whole of the epiphysis was full of hemopoietic marrow; these were both from men aged thirty-six. Their illness or the treatment administered before death might have had some influence on the amount of the hemopoietic marrow, which we believe is quite exceptional.

Together with this study of spontaneous variations of the blood supply of the femoral neck, we made an attempt to modify the blood flow by ligating the vessels which supply the various groups of arteries, or by resecting the capsule.

Ligation of the profunda femoris artery and of the origin of the circumflex arteries

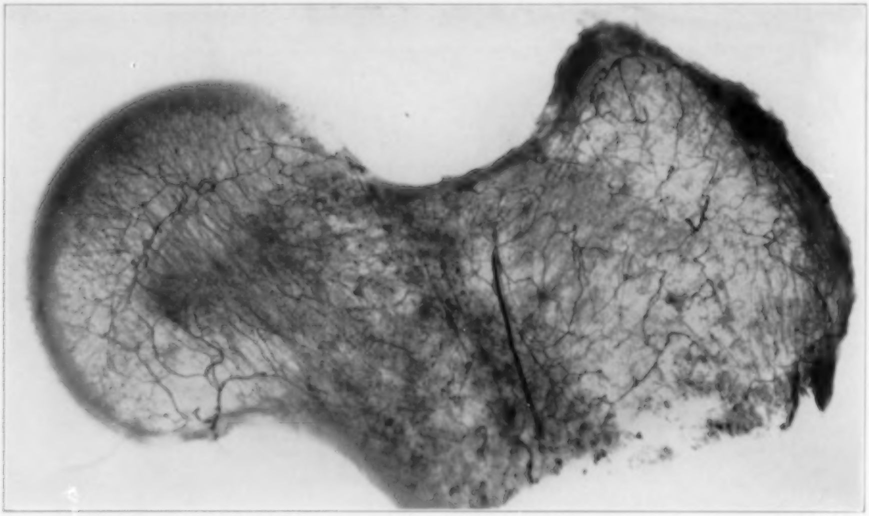

FIG. 14

The injection was made after Gibson's approach with division of the abductor muscles.

does not diminish as much as could be expected the blood supply either to the neck or to the head. In all cases, the main groups were injected. In two cases, filling seemed inadequate, but in the others it was complete. On the same subject, we ligated on one side the circumflex arteries, the quadriceps artery, and the superficialis femoris ten centimeters below the origin of the profunda femoris; on the other side, we ligated the profunda femoris below the origin of the circumflex arteries and the superficialis femoris two centimeters below the origin of the profunda femoris. The injection was made through the lateral iliac artery and the results of both injections were quite similar. All of the main arteries of the neck, as well as those of the head, were injected.

In another series of injections, we resected the capsule. A complete anterior and posterior capsulectomy, provided it does not destroy the femoral capsular insertions, very noticeably decreases the blood flow of the head, but does not interfere with the vascularization of the neck. If, on the other hand, the capsular insertions on the femur are destroyed by stripping or scarification, the vascular supply of the epiphysis is almost completely interrupted.

The resection of a strip from the anterior capsule anteriorly and posteriorly, as is sometimes done in operations on the hip, has no effect on the blood supply either of the neck or of the head.

Therefore, the richness of arterial anastomoses around the joint seems such as to allow the ligature of a great number of peripheral arteries without any serious damage to the blood flow to the epiphysis. On the other hand, destruction of the lateral capsular attachments by stripping of the superior rim of the neck, with resultant tearing of the synovial membrane under which the vessels run, serves to diminish the blood supply noticeably.

This study has served to define more precisely certain conditions of the vascularization of the femoral neck. These findings are of direct clinical interest on many occasions, particularly for studying the approaches to the hip, the arthroplastic procedures with use of prostheses, and some of the problems encountered in fractures of the neck.

SURGICAL APPROACHES TO THE HIP

As has been mentioned, the blood supply to the neck has not been affected by tying the vessels around the upper part of the femur. The medial or the lateral circumflex artery,

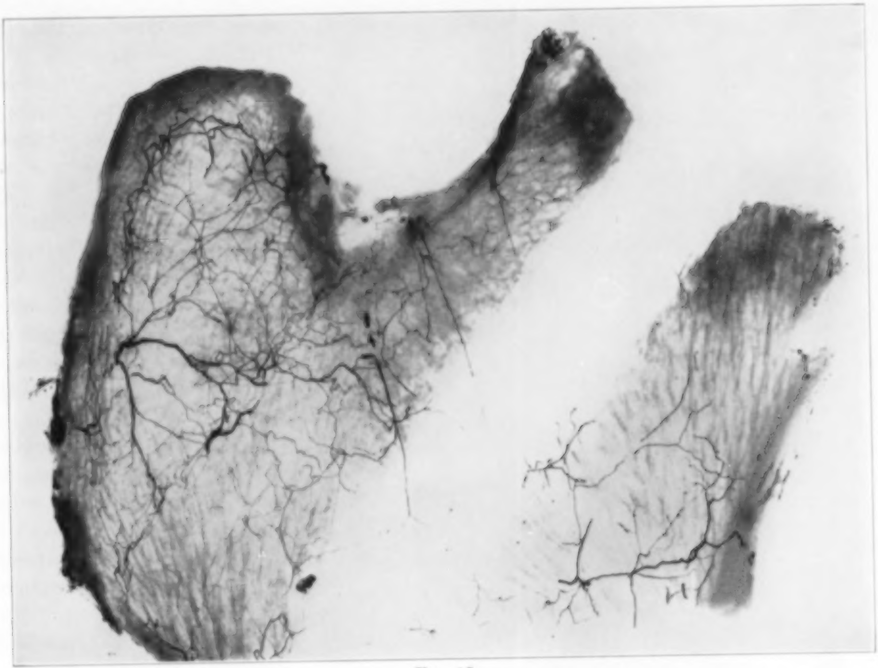

FIG. 15

Frontal slice. The injection was made after arthroplasty, with insertion of an acrylic prosthesis, had been performed on the cadaver.

or both, could be ligated without changing the appearance in the arteriogram after injection.

We also stated that the T incision of the capsule and even a capsulectomy limited to the proximal part of the capsule do not damage either the metaphyseal or the epiphyseal vascularization.

These statements were confirmed by performing on fifteen subjects the complete routine operative procedures of various approaches to the hip. The injected specimen was then compared with the other side whenever possible.

Of seven cases in which the approach was through Hueter's straight anterior incision, no change in the vascularization of either the head or the neck was found.

In eight cases approached through Gibson's posterolateral incision (detaching of the superior surface of the trochanter or division of the abductor muscles), no important or constant vascular change was found (Fig. 14).

Finally, we believe that, whatever approach is used, in order to spare the blood supply for the head and the neck after exposure of the joint, certain rules should be followed:

Extensive distal capsulectomies and, above all, destruction of the lateral capsular attachment, which may severely damage the vascular supply must be avoided.

The sites, pattern, and importance of the superior arteries of the neck must be remembered and any procedure harmful to them must be avoided.

Lastly, the surgeon should be careful not to disturb the synovial membrane which covers the bone around the neck and under which the vessels course.

HIP ARTHROPLASTY

In hip arthroplasty with insertion of a prosthesis, two procedures change consider-

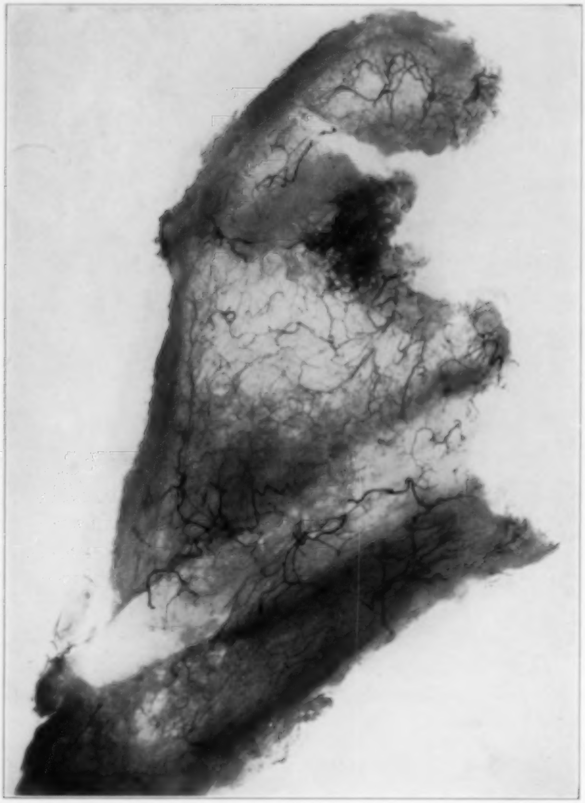

FIG. 16

Frontal slice. The injection was made two years after an arthroplasty with an acrylic head for fracture of the neck.

ably the vascularization of the cervical stump:

1. *Drilling the central part of the neck* destroys numerous intra-osseous branches of the superior group of the cervical arteries. Only the branches running near the anterior or posterior cortex can be left untouched.

2. *Reaming of the cervical stump* in order to adjust the size of the neck to the collar of the prosthesis destroys the peripheral vascularization of the distal part of the cervical stump, as well as the medial inferior group of arteries. Thus, this area, deprived of its supply from the superior group, lacking its peripheral circulation, is left in a precarious condition of vascularization (Fig. 15).

These findings were confirmed by performing eight arthroplasties on cadavera before injection. The study of such specimens showed a considerable decrease of the arterial circulation in the entire lower half of the neck, both in the cancellous bone and the inferior cortex. The latter is supplied only by some vessels from the lateral inferior group and, in several cases, no vessel was found to be injected in this area.

The consequences of this vascular disturbance are certainly important, both for the postoperative course and for the fate of arthroplasties in general.

The destruction of the superior group of arteries in the neck is compensated by a considerable increase in the peripheral circulation which will supply the cancellous and compact bone tissues.

We had the opportunity to inject the hip of a subject two years after an arthroplasty had been performed. A considerable disturbance of the vascular meshwork was seen, but we were able to demonstrate the revascularization of the lower part of the neck through new vessels, the pattern of which was entirely different from that of the original vessels (Fig. 16).

Thus, for several months, the area in the cervical stump which supports the prosthesis is the very area where these vascular changes are taking place. It is evident that, if, during the same period, an unusually strong pressure is sustained by that area, it will not heal well.

The above findings may explain the enlargement of the canal for the prosthesis, which causes most of the loosening observed in such cases.

Vascular damage is sustained at the time of the operation; however, its consequences

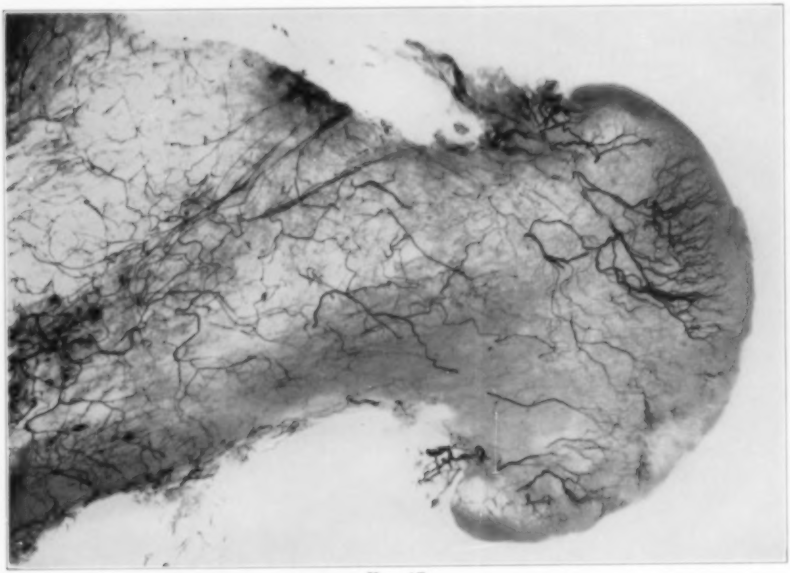

FIG. 17

Frontal slice, taken from a subject with osteo-arthritis.

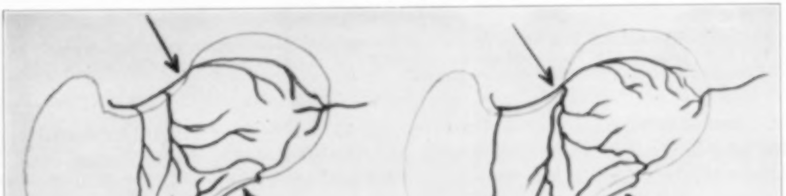

FIG. 18

Drawings illustrating the most common types of arterial patterns in the neck and the effect of fracture upon these patterns. The gray zones show the areas in which the arterial supply is jeopardized by fracture.

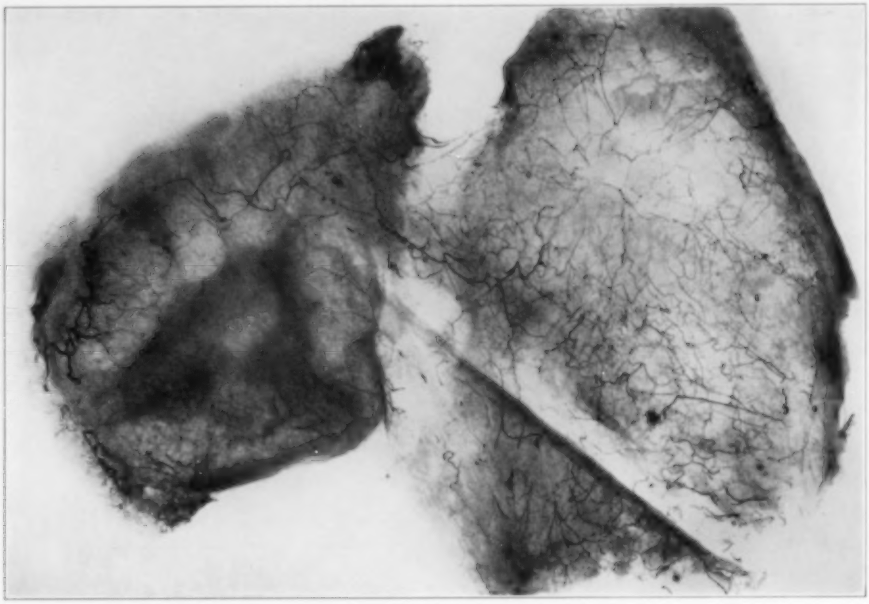

FIG. 19-A

Frontal slice. The subject had had a fracture of the neck which had been nailed five years previously. Note the deformity of the head, the central necrosis and peripheral revascularization, as well as the arterial reorganization in the neck around the nail.

are not demonstrated clinically and roentgenographically until several months later. This explains why in some cases the functional and roentgenographic results seem excellent for several months, after which they gradually become altered.

Necrosis of the cervical stump can be followed on the basis of clinical rating tables as well as by roentgenograms. When there is no further progress of the lesion, stabilization is evident roentgenographically and clinically.

These conclusions seem applicable to all arthroplasties, including arthroplasties for osteo-arthritis; in the latter condition, the vascular changes in the head are considerable, as was stated by Trueta and Harrison and as was observed in the present study. These changes, however, produce a hypervascular rather than hypovascular state; moreover, the arterial groups of the neck were found intact in all the specimens.

Conclusions

These findings lead to the following conclusions:

All procedures which jeopardize the superior group of arteries must be avoided.

Prostheses with a stem as narrow as possible must be used, in order to spare as many intra-osseous vessels as possible.

Reaming and shaping of the neck is a dangerous operative procedure which may result in a weakening of the area which supports the prosthesis.

Too early weight-bearing must be proscribed.

For the past twenty-eight months, we have used a new design for the prosthesis, which was made essentially for a better redistribution of pressure on the cervical stump; however, it has several advantages as far as vascularization is concerned:

1. The diameter of the stem is smaller.

2. The collar has been given up; therefore, shaping the neck by means of a reamer is unnecessary. Reoperations performed in earlier cases had demonstrated frequent necrosis

of the area covered by acrylic.

3. During oblique resection of the head, the inferior medial group of arteries is left intact; its contribution to the vascular supply of both the inferior cortex and the cancellous bone of the neck has been mentioned above.

All of these factors may improve the postoperative course in the future.

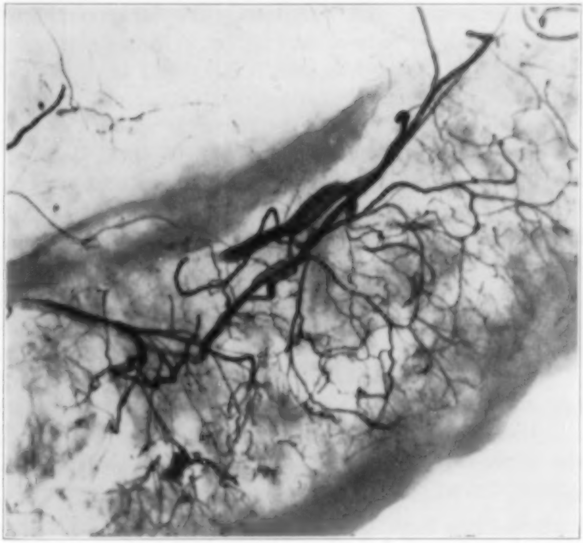

FIG. 19-B

Enlargement of an osteophyte of the inferior part of the head. New vessels passing through the cartilage covering the head have formed the osteophyte.

FRACTURES OF THE NECK

In fractures of the neck, the prognosis does not rest on vascular factors alone. This problem has been studied by many authors [1,7,10,15,16,17]. Most of these authors have attempted to establish more precisely the contribution of the ligamentum teres artery to the vascular supply. Their main concern was the fate of the head which has been deprived of its main arterial group. The importance of the vascularization of the head should not be overlooked, but we believe that the vascular condition of the stump must also be considered.

It is now an accepted fact, confirmed by our experiments, that the blood supply through the ligamentum teres does not decrease with age; Nordenson even thinks it increases.

It is also an accepted fact that the degree of vascular damage is in proportion to the displacement of the fracture fragments. A slight forward displacement of the fractured surface certainly leaves unchanged the majority of posterior and superior vessels. The displacement itself is related to the obliquity of the fracture line. When the angle made by the fracture line with the axis of the diaphysis [4] is acute (less than 40 degrees), the displacement may be significant. When this angle is wide, the displacement is always moderate. The latter type of fracture heals more easily than the former. Thus, we are brought back to the theories developed by Pauwels, which are based upon mechanical considerations.

In all types of fractures with marked displacement, whatever the site and the direction of the fracture line, the capital fragment is deprived of most of its vascular supply and what remains is insufficient to maintain viability of bone tissue. Therefore, for nutrition and for healing, the head fragment needs vessels coming from the neck.

However, the vascularization of the neck can also be affected by the very site of the fracture.

We have pointed out that in a number of cases (20 per cent. of the specimens examined) the main arterial group of the neck issued from a bifurcation of the cervicocapital arteries; this bifurcation may even be found in the head in some cases. If such a neck is fractured—that is, if there is a subcapital fracture or a transcervical fracture close to the head—the main part of the superior arterial group, as well as the medial inferior group, is destroyed. The only arteries remaining are the two or three belonging to the superior group which penerate the neck proximal to the trochanter, coursing toward the diaphysis.

Thus, a major part of the neck will be lacking in normal vascularization and, when the fracture has been reduced and nailed, both contacting fragments will be poorly vascularized (Fig. 18). In such a case, it is evident that, if the reduction of the fracture is not perfect, if immobilization is not complete, and if weight-bearing is started too early, all of these factors will result in a pseudarthrosis with resorption of the neck.

However, sometimes such fractures do heal, because of revascularization, first of the neck, and then of the head. This involves two processes: First, creeping substitution, described by Phemister and recently demonstrated experimentally by Tovee. This, however, requires perfect reduction and strict and prolonged immobilization. The second process is that of peripheral vascularization. This may occur even with an imperfect reduction, but vascularization remains abnormal; such abnormal vascularization results in deformities of the head, which remains poorly nourished in its center and is unexpectedly bordered by hypervascularized osteophytes (Figs. 19-A and 19-B).

Such factors might be the explanation for certain cases of shortening of the neck and for some pseudarthroses which occur even after proper treatment.

Finally, the case of fractures at the base of the neck, in which the fracture line follows the capsular insertion, is different. Such fractures heal badly, probably because they interrupt most of the arterial supply of the neck which will have to re-form later.

Note: This work was performed, in part, in the *Laboratoire d'Étude de l'Os et de la Croissance*, of the *Faculté de Médecine de Paris, Service du Prof. M. Fèvre*, with the cooperation of Prof. Agrégé Cartier, to whom we extend our thanks.

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FRACTURES OF THE HUMERUS

A Comparative Study in Methods of Treatment *

BY MARCUS J. STEWART, M.D., AND JOHN M. HUNDLEY, M.D., MEMPHIS, TENNESSEE

From the Campbell Foundation and the Department of Orthopaedic Surgery,
University of Tennessee College of Medicine, Memphis

Prior to 1940, fracture of the humerus was the leading contender for the development of non-union in the fractures of long bones [15]. In that year, Caldwell [3], reporting a group of these fractures treated by means of the hanging cast, a method which he first advocated using in 1933 [2], revolutionized the treatment and removed the humerus from this position of unfavorable distinction [2, 4, 6–9, 11, 13–14, 16].

Over thirty years ago, Leriche and Policard pointed out that motion and breaking of the new callus at a fracture site would cause additional hemorrhage, embryonic fibrous tissue, and more abundant callus. Thus, fractures of bones with a rich blood supply, such as the rib, femur, or humerus, where there is slight motion at the fracture site, usually heal rapidly, provided that there is no infection or mechanical interference, such as exces-

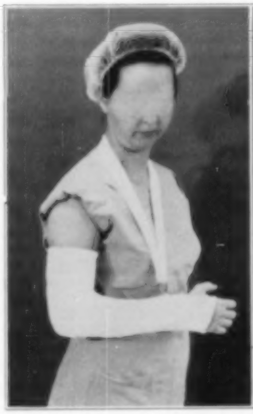

FIG. 1-A

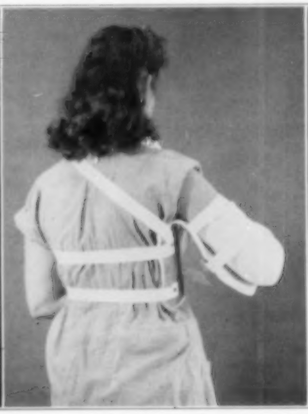

FIG. 1-B

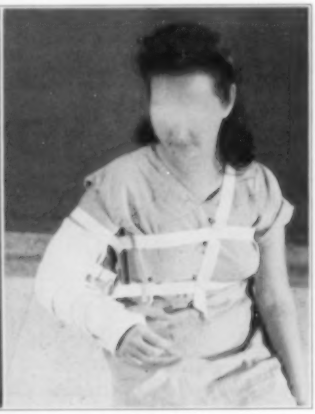

FIG. 1-C

Fig. 1-A: Hanging cast in position for treatment of a fracture at the junction of the middle and proximal thirds of the humeral shaft. The points of traction are through the sling and the arm. Angulation may be changed and controlled by shortening or lengthening the sling or by placing the wire loop at the wrist on the dorsal or the volar side of the cast.

Figs. 1-B and 1-C: During the first few days of treatment, the patient is often more comfortable if the arm and cast are supported on an abduction humerus splint. The splint is curved outward at the elbow to hold the humerus in straight alignment. For children under twelve years of age, the splint is used throughout the period of treatment.

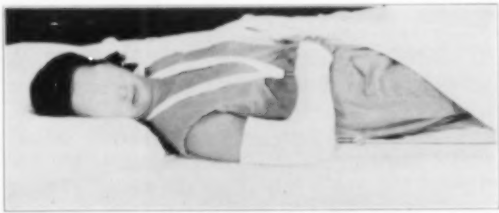

FIG. 1-D

Fig. 1-D: The patient who must be recumbent should have three to five pounds of traction pulling from a fixed point in the area of the olecranon and in line with the humerus. The sling in its usual position maintains position of the forearm.

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* Presented in part at the Annual Meeting of the Southern Medical Association, Dallas, Texas, November 7, 1951.

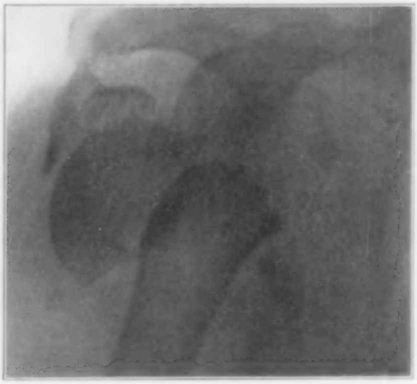

Fig. 2-A

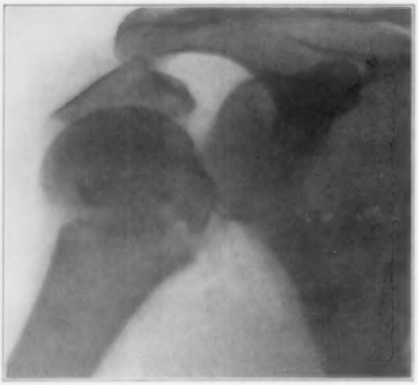

Fig. 2-B

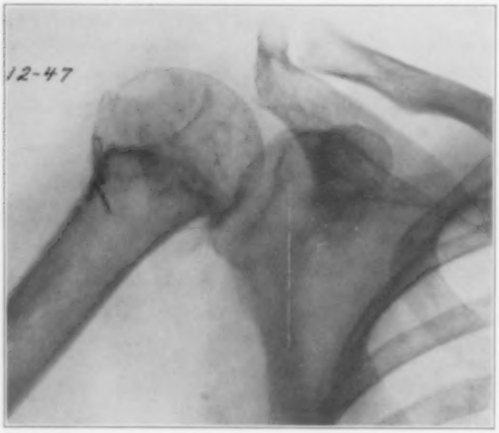

Fig. 2-C

Fig. 2-A: Roentgenogram made June 9, 1947, of an abduction fracture of the surgical neck of the humerus; the greater tubercle has been "squeezed off". Open reduction and internal fixation were necessary. Resection of the acromion aids abduction and facilitates recovery in a fracture of this type.

Fig. 2-B: Roentgenogram made June 16, 1947, after reduction and internal fixation.

Fig. 2-C: Follow-up roentgenogram made December 12, 1947.

sive trauma, interposition of soft tissue, gross malposition, internal fixation, or compounding. The distal portions of the tibia and ulna and other bones with a more limited blood supply heal slowly and require rigid, uninterrupted immobilization.

Rigid immobilization of a fracture in a long bone is difficult with internal fixation and impossible with external fixation [15]. Fixation of a fractured humerus in a body plaster will not only fail to hold the fragments rigid but also will prevent exercise of the soft tissue and will thus lead to the pitfalls of inactivity,—that is, muscle atrophy, osteoporosis, and adhesions of muscles, tendons, and joints [3].

New-bone production is the result of a proper balance between osteolysis or osteoclasis and osteogenesis. This can best be accomplished if there is good muscle function which enhances the blood supply. The method of treatment which permits consistent active exercise [5], therefore, is the one most conducive to early and firm union. Moreover, exercise encourages restoration of function, which is as desirable as anatomical position and solid bony union.

There is nothing new about the hanging cast [10] (Figs. 1-A through 1-D). The authors have found it of value in the treatment of various types of fractures of the humerus. However, fractures of the humerus in children under the age of twelve should not be treated with the hanging-cast method *per se*. It is practically impossible to keep the arm in the dependent position while the child is asleep. Also, during the waking hours the child will often support the arm or elbow so that traction is not maintained. We have found, however, that a long arm cast supported on an abduction humerus splint, as illustrated in Figures 1-B and 1-C, is usually an adequate method of treatment.

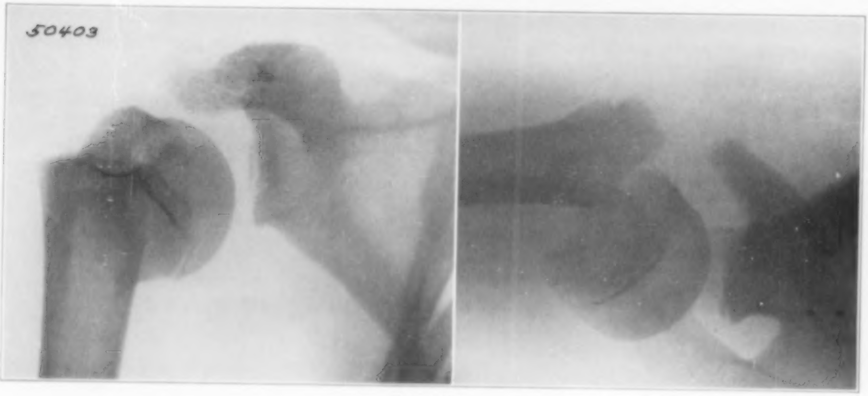

FIG. 3-A

Roentgenograms made September 5, 1940, showed an adduction fracture with epiphyseal separation in a fifteen-year-old boy. He had had three unsuccessful manipulations prior to coming to the Clinic. At surgery, the biceps tendon and the periosteum were found caught between the fracture surfaces. After removal of these tissues, reduction was easily accomplished. The fracture was fixed with a wire loop. Active motion was begun at two weeks.

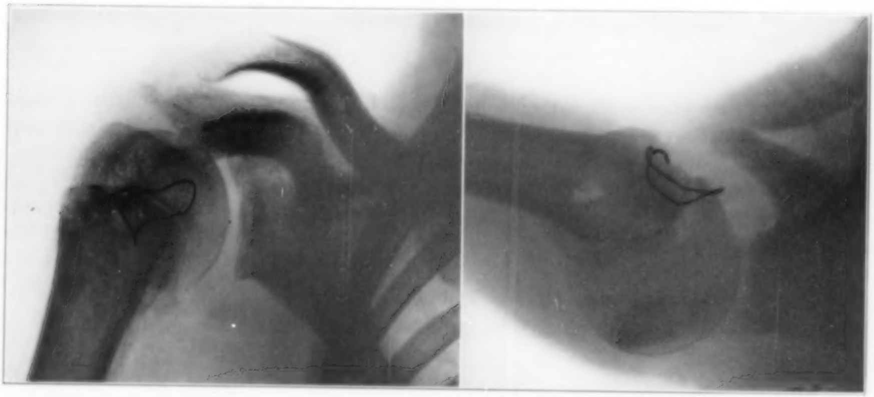

FIG. 3-B

Roentgenograms made October 18, 1940. After five weeks, the patient had a full range of painless motion.

SELECTION OF CASES

We have reviewed more than 1,000 cases of fracture of the humerus treated at the Campbell Clinic, covering the era of the so-called "rigid plaster fixation" through the present stage of the hanging cast, a period of fifteen years. Patients with fractures involving the elbow joint, those followed less than six months, and those who were initially treated elsewhere were excluded. Included were patients with fractures of the neck, shaft, and head of the humerus. A total of 546 cases were adequately followed; these comprised 271 fractures of the neck, 223 of the shaft, and 52 of the head. The fractures of the neck and shaft have been studied with respect to the type of treatment and results.

EVALUATION OF RESULTS

Our classification of results is as follows:

Excellent: No pain or impairment of function and no roentgenographic evidence of deformity;

TABLE I

Treatment of Fractures of the Neck of the Humerus with the Abduction Humerus Splint

(206 Cases)

		No. of Patients	Per Cent.	
Age				
Range, 5 to 84 years				
Average, 44 years				
Sex				
Male		85	41.2	
Female		121	58.7	
Other Factors				
Anaesthesia used		70	33.5	
Associated fractures present		35	16.9	
Average period of immobilization	3.8 weeks			
Results				
Excellent		117	56.8	83.5
Good		55	26.7	
Fair		24	11.6	16.5
Poor		10	4.8	

Good: No pain and no impairment of function for ordinary purposes, but with limitation of motion in the elbow or shoulder of 20 per cent. or less, and with solid bony union and angulation of not more than 10 degrees;

Fair: Solid bony union with occasional mild pain, angulation of more than 10 degrees, or limitation of motion in adjacent joints of more than 20 per cent., but with satisfactory function for light duties;

TABLE II

Treatment of Fractures of the Neck of the Humerus with Slings and Bandages

(32 Cases)

		No. of Patients	Per Cent.	
Age				
Range, 11 to 78 years				
Average, 44 years				
Sex				
Male		9	28.1	
Female		23	71.9	
Other Factors				
Anaesthesia used		3	9.4	
Associated fractures present		5	15.6	
Average period of immobilization	4.5 weeks			
Results				
Excellent		20	62.5	84.4
Good		7	21.9	
Fair		3	9.4	15.6
Poor		2	6.2	

TABLE III

Treatment of Fractures of the Neck of the Humerus with the Hanging Cast

(33 Cases)

		No. of Patients	Per Cent.	
Age				
Range, 6 to 72 years				
Average, 42 years				
Sex				
Male		15	45.5	
Female		18	54.5	
Other Factors				
Anaesthesia used		4	12.1	
Associated fractures present		2	6.1	
Average period of immobilization	4.8 weeks			
Results				
Excellent		28	84.8	96.9
Good		4	12.1	
Fair		1	3.0	

Poor: Persistent pain, limitation of motion in an adjacent joint of 40 per cent., and with non-union or malposition and impairment of function.

FRACTURES OF THE NECK OF THE HUMERUS

Although the physiological age of the patient influences the choice and extent of treatment, in dealing with fractures of the neck of the humerus, we have chosen sixty years as an arbitrary age for definitive treatment. With few exceptions, patients beyond this age can tolerate a residual limitation of function without material inconvenience.

Fractures of the surgical neck of the humerus are of three types: (1) transverse (with or without impaction), (2) abduction, and (3) adduction.

Transverse Fracture

The transverse fracture seldom requires any treatment other than a collar-and-cuff sling, with early, active exercise.

Abduction Fracture

The abduction fracture is most common in adults. If the fragments are impacted and if the patient is over sixty years of age, conservative treatment with slings and bandages is indicated. In the younger patient, the impaction should be disengaged, and the fracture should be reduced and the extremity immobilized in a position of adduction. A hanging cast is excellent for this type of fracture; it is not only the procedure of choice for continued immobilization, but also, in many cases, it will effect a satisfactory reduction.

If the abduction fracture is not impacted, the greater tubercle is invariably found to be "squeezed off" between the head and the shaft and is elevated by the rotator cuff until it rides against the acromion. This injury requires open reduction and internal fixation by means of stainless-steel screws or wire loops; catgut or silk-suture fixation is not adequate (Figs. 2-A through 2-C). Following reduction, the hanging cast provides the best method of immobilization, although an abduction splint may be applied in a position of less than 15 degrees of abduction, if strong traction and countertraction are utilized. When this fracture is allowed to heal without accurate replacement of the greater tubercle,

TABLE IV

Treatment of Fractures of the Shaft of the Humerus with the Abduction Humerus Splint

(63 Cases)

		No. of Patients	Per Cent.	
Age				
Range, 2 to 87 years				
Average, 28.5 years				
Sex				
Male		30	47.6	
Female		33	52.4	
Type of Fracture				
Transverse		24	38.1	
Spiral and oblique		23	36.5	
Badly comminuted		16	25.4	
Other Factors				
Anaesthesia used		19	30.2	
Associated fractures present		8	12.7	
Average period of immobilization	6.1 weeks			
Results				
Excellent		43	68.3	88.9
Good		13	20.6	
Fair		4	6.3	11.1
Poor		3	4.8	
Non-union		None		

TABLE V

Treatment of Fractures of the Shaft of the Humerus with a Plaster-of-Paris Cast

(53 Cases)

		No. of Patients	Per Cent.	
Age				
Range, 2 to 79 years				
Average, 35.5 years				
Sex				
Male		27	50.9	
Female		26	49.1	
Type of Fracture				
Transverse		18	33.9	
Spiral and oblique		15	28.3	
Badly comminuted		20	37.7	
Other Factors				
Anaesthesia used		45	84.9	
Associated fractures present		20	37.7	
Average period of immobilization	10.4 weeks			
Results				
Excellent		22	41.5	71.7
Good		16	30.2	
Fair		12	22.6	26.5
Poor		2	3.9	
Non-union		1	1.8	

TABLE VI

TREATMENT OF FRACTURES OF THE SHAFT OF THE HUMERUS WITH THE HANGING CAST

(107 Cases)

		No. of Patients	Per Cent.	
Age				
Range, 10 to 79 years				
Average, 36 years				
Sex				
Male		68	63.6	
Female		39	36.4	
Type of Fracture				
Transverse		15	14.0	
Spiral and oblique		70	65.4	
Badly comminuted		22	20.6	
Other Factors				
Anaesthesia used		12	11.2 *	
Associated fractures present		12	11.2	
Average period of immobilization	6 weeks			
Results				
Excellent		87	81.3	93.5
Good		13	12.2	
Fair		4	3.7	6.5
Non-union		3	2.8	

* Five patients had open fractures.

abduction will be markedly restricted. In neglected cases, resection of the acromion, and transfer of the greater tubercle with re-attachment of the rotator cuff to the shaft are necessary to restore function.

Adduction Fracture

The third type of fracture of the surgical neck, the adduction fracture, must be reduced; otherwise, permanent limitation of abduction with considerable loss of function will follow. Reduction is effected by traction and abduction, and immobilization is continued in this position for three to four weeks. A light hanging cast supported on an abduction splint with the extremity in abduction of approximately 60 degrees is ideal. The splint may be employed alone, provided that skin traction is continuously maintained. Unless adequate abduction is maintained until the fracture is solidly united, the deformity may recur.

In individuals over sixty years of age, the same treatment is employed; however, active exercises are begun earlier even if perfect alignment is sacrificed, in order to continue function.

The adduction fracture is the most common type involving the shoulder in children, and it must be accurately reduced. Interposition of the biceps tendon is often a complication, especially if the fracture is associated with epiphyseal dislocation. If manipulation fails, open reduction is necessary. A wire loop or a screw is inserted for internal fixation. Active motion is begun after two or three weeks, and normal function may be expected in three months. If the child is young. the parents should be warned of the rare possibility of disturbance of epiphyseal growth.

Results of Conservative Treatment

We have adequate follow-up reports on 271 fractures of the neck of the humerus

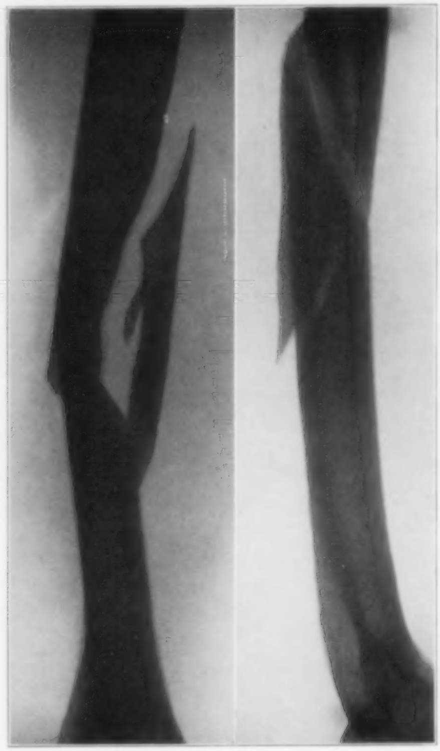

Fig. 4-A

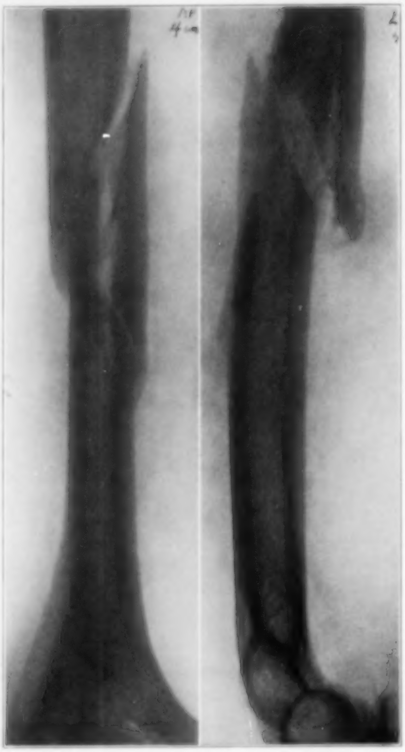

Fig. 4-B

Fig. 4-A: Roentgenograms made September 7, 1941, showed an oblique or spiral fracture of the midshaft of the humerus in a man, aged thirty-nine years.

Fig. 4-B: Roentgenograms made October 5, 1941, showed solid union at four weeks. Function was normal at four months after removal of the cast.

treated by non-operative methods. Table I shows the results in 206 cases following treatment with the abduction humerus splint; Table II, the results in thirty-two cases following the use of slings and bandages; and Table III, in thirty-three cases in which the hanging cast was employed. The fractures in which only slings and bandages were used were uniformly less severe.

The hanging cast is a relatively recent innovation at the Clinic in the treatment of fractures of the neck of the humerus. The increase in the percentage of good and excellent results following its use as compared with those following the use of the abduction splint is noteworthy, and even more significant is the decrease in the number of patients requiring anaesthesia. We are learning that the hanging cast, when properly employed, will reduce many adduction fractures and practically all abduction fractures.

FRACTURES OF THE SHAFT OF THE HUMERUS

As a rule, oblique, spiral, and comminuted fractures of the shaft will heal rapidly. The simple uncomminuted injury demands the most meticulous care; some fail to unite because of lack of attention to minor details.

The hanging cast is the method of choice in treating fractures of the shaft, regardless of type or location, provided the following rules are scrupulously observed:

1. The plaster must be light and never a distracting force.
2. The elbow must be in flexion of 90 degrees, and the plaster should extend from

the mid-palm to the fracture level or not more than one inch above.

3. The sling must be fixed at the level of the wrist.

4. To correct lateral angulation, the loop should be placed on the dorsum of the wrist; to correct medial angulation, the loop should be placed over the volar side.

5. A long sling should be used to correct posterior angulation; a short one, to correct anterior angulation.

6. The arm must be continuously dependent,—that is, in traction.

7. Anteroposterior and lateral roentgenograms should be made at weekly intervals, or more often if indicated.

8. Early, active, vigorous exercises of the "longitudinal muscles"[6] of the shoulder (four to six times daily) are imperative.

9. Systematic resistance exercises of the fingers and thumb are essential.

10. If the patient must remain recumbent, traction must be maintained at the elbow in line with the humerus (Fig. 1-D).

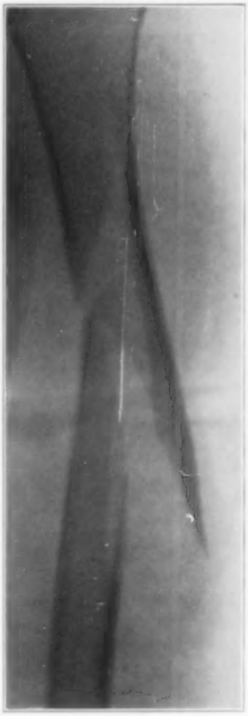

FIG. 5-A
May 3, 1948.

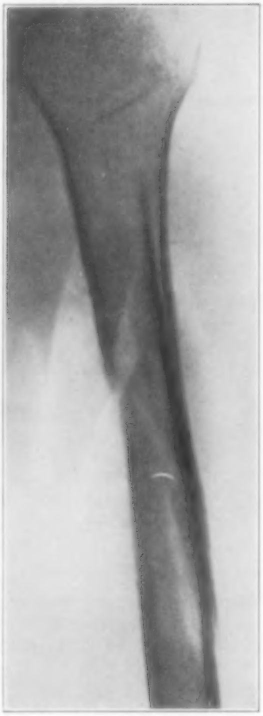

FIG. 5-B
June 26, 1948.

Results of Conservative Treatment

We have an adequate follow-up on 223 fractures of the shaft treated without surgery. Table IV shows the results in sixty-three cases in which the abduction traction humerus splint was employed. Table V shows the results in fifty-three cases treated by a plaster body cast. It is noteworthy that 85 per cent. of these patients required anaesthesia, and that the average period of immobilization was 10.4 weeks. Table VI shows the results in 107 cases treated by the hanging cast. Anaesthesia was necessary in only twelve patients, or 11 per cent., and five of these patients had open fractures requiring débridement. Immobilization was maintained for an average of only six weeks. Good and excellent results were obtained by this method in 95 per cent. of the cases, as compared to 71.6 per cent. in the group treated in a body spica.

The three ununited fractures following treatment by a hanging cast were due to excessive weight, resulting in distraction, and inadequate muscle exercise. We now insist upon a lighter plaster and early, active exercise.

For the treatment of oblique or spiral fractures of the mid-shaft of the humerus, the hanging cast is ideal. Figures 4-A and 4-B illustrate such a fracture in a man, thirty-nine years of age, treated in this manner. Union was clinically solid at four weeks, and function was normal, with complete motion in the joints, at four months.

A fracture below the insertion of the deltoid produces abduction of the proximal fragment. Treatment in a hanging cast is effective if the sling is attached to the dorsum of the wrist to correct lateral angulation. Figures 5-A and 5-B show a fracture of this type

TABLE VII

Summary of End Results in the Treatment of Fractures of the Humerus

(494 Cases)

Type of Immobilization	No. of Cases	Excellent (*Per cent.*)	Good (*Per cent.*)	Excellent and Good (*Per cent.*)	Fair (*Per cent.*)	Poor (*Per cent.*)	Non-Union (*Per cent.*)	Fair, Poor, and Non-Union (*Per cent.*)
Fractures of the Neck of the Humerus								
Abduction humerus splint	206	57.	27.	84.	11.	5.	0.	16.
Slings and bandages	32	63.	22.	85.	9.	6.	0.	15.
Hanging cast	33	85.	12.	97.	3.	0.	0.	3.
Total	271							
Fractures of the Shaft of the Humerus								
Abduction humerus splint	63	68.	21.	89.	6.	5.	0.	11.
Plaster-of-Paris cast	53	41.	30.	71.	23.	4.	2.	29.
Hanging cast	107	81.	12.	93.	4.	0.	3.	7.
Total	223							

treated by a hanging cast. Union was solid at six weeks and the result was excellent.

Figures 6-A and 6-B illustrate a transverse fracture with abundant callus one month

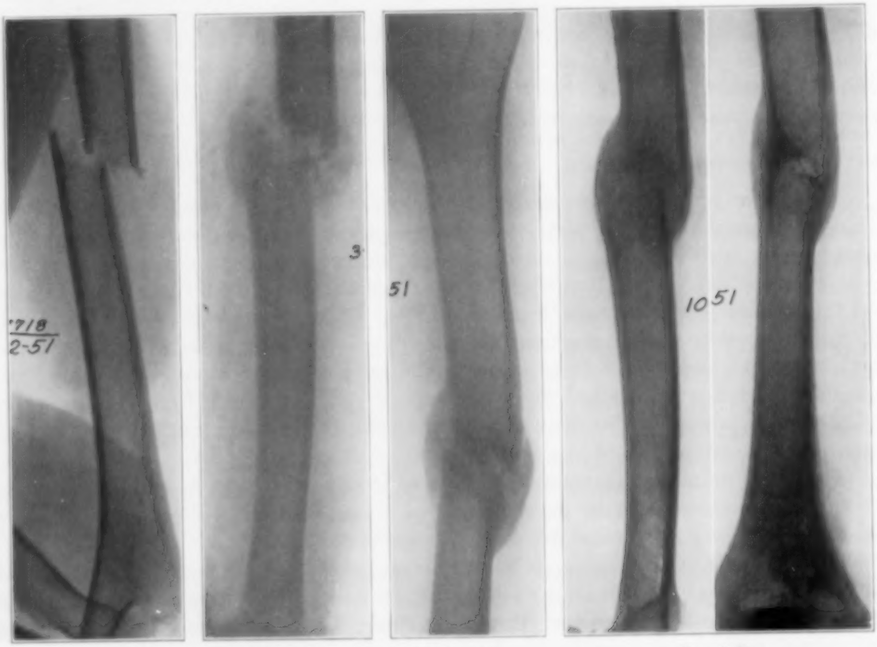

Fig. 6-A February 2, 1951. Fig. 6-B March 6, 1951. Fig. 6-C June 6, 1951. Fig. 6-D October 30, 1951.

Roentgenograms made of a transverse fracture of the shaft. Callus formation was excellent at one month, and union was solid at two months. The shaft was well remodeled at nine months.

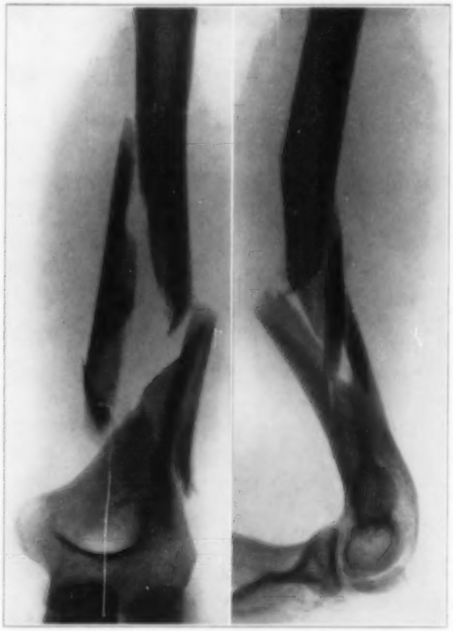

FIG. 7-A

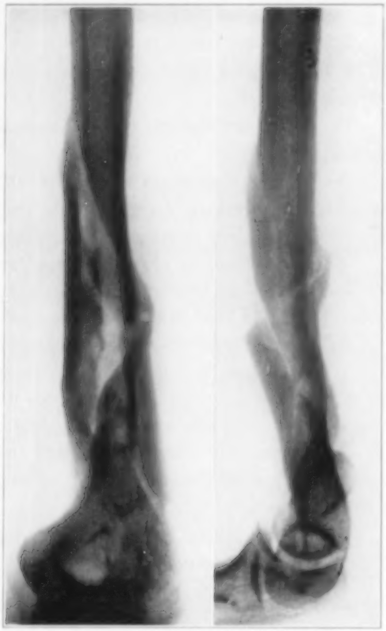

FIG. 7-B

Fig. 7-A: Roentgenogram made April 20, 1947.

Fig. 7-B: Roentgenogram made August 27, 1947, when recovery was complete.

after injury and immobilization in a hanging cast. At two months, there was clinical union. The results at four and eight months are shown (Figs. 6-C and 6-D).

Fractures in the distal third of the shaft reputedly should not be treated by the hanging cast, because angulation is difficult to control. We have found, however, that a comminuted fracture in the distal third may be satisfactorily treated with the hanging cast, provided that the forearm is placed in pronation and the sling is attached along the ulnar border at the level of the wrist. This counteracts the supination effect of the biceps muscle on the fracture, thus correcting the lateral angulation.

A comminuted fracture of the distal third of the shaft in a woman, forty-eight years of age, is shown in Figure 7-A. After ten days of treatment in a hanging cast, the alignment was excellent. At eight weeks, union was solid, and at four months recovery was complete (Fig. 7-B), with normal function of the extremity.

Table VII gives a comparison of the methods of treating fractures of the neck and shaft of the humerus. For fracture of the neck, many methods, when properly employed, may be satisfactory. The hanging cast, however, is consistently superior.

Fractures of the shaft are best treated by the hanging cast. The abduction splint may often be used to advantage as an adjunct to treatment, although it requires close and continual observation. There is seldom any indication for use of the shoulder spica.

FRACTURES OF THE HEAD OF THE HUMERUS

These injuries are classically of two types: split head and severely comminuted. Either may be associated with dislocation from the glenoid. Open reduction is mandatory if a good functional result is to be expected.

Since fractures of the head of the humerus will be discussed in a later article, a report of the end results of treatment of this type of fracture is not included in this paper.

CONCLUSIONS

Undisplaced fractures of the neck of the humerus or impacted fractures in patients of the older age group (over sixty) are best treated by a collar-and-cuff sling and early, active exercise [5].

Impacted adduction fractures of the neck must be reduced and immobilized in abduction.

As a rule, abduction fractures without avulsion of the greater tubercle may be reduced by manipulation and immobilized in a hanging cast. If the tubercle and rotator cuff are displaced, they must be reduced accurately, usually by surgery.

The treatment of choice for all fractures of the shaft at any level is the hanging cast, provided: (1) that traction is never excessive; (2) that angulation and apposition are controlled; and (3) that the "hanging-cast rules" are observed.

Although fractures of the shaft may be treated successfully by the abduction splint, return of function will be delayed, the apparatus will require continual attention, and the patient will be less comfortable than with the hanging cast.

The shoulder spica is rarely indicated in the treatment of any fracture of the humerus.

Anaesthesia is seldom necessary for reduction of uncomplicated fractures of the neck or shaft, provided that traction is properly utilized. Thus, the necessity for hospitalization is reduced to a minimum.

Since medullary fixation is gaining wide popularity, it is well to re-emphasize the success of conservative treatment of these fractures.

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A NEW PRINCIPLE IN THE OPERATIVE TREATMENT OF TROCHANTERIC FRACTURES OF THE FEMUR

BY DR. W. SCHUMPELICK AND DR. P. M. JANTZEN, HAMBURG, GERMANY

From the Hafenkrankenhaus, Hamburg

The superiority of operative treatment of trochanteric fractures in respect to the survival rate and the anatomical and functional results is acknowledged by the majority of authors, and the nail-plate is the method now most frequently used for internal fixation of these fractures. The purpose of this article is to introduce a new principle designed to avoid the various complications of the nail-plate.

These complications chiefly are: (1) protrusion of the nail into the hip joint and even into the pelvis; (2) cutting upward of the nail through the cancellous bone of the femoral head and neck; (3) bending and breaking of the nail, usually at its weakest point, the angle; (4) detachment of the plate from the shaft, due to loosening of the screws; and (5) loosening of a screw which unites the nail and the plate.

The chief reason for all of these complications is the rigid union of the nail and the plate. If the nail has been driven in as far as the thin cortex of the femoral head, it will protrude into the joint as absorption takes place at the fracture site and muscle pull or weight-bearing brings the fragments together. If, on the other hand, the nail is not driven to within ten to fifteen millimeters of the articular margin, its tip will be insecurely fixed, the nail will cut upward, and the result will be a coxa vara.

DESCRIPTION OF THE GLIDING SCREW-PLATE

The screw-plate (Fig. 1), developed by Ernst Pohl in Kiel, allows the screw, which is used in place of the nail, to glide out in the same way that a Smith-Petersen nail, in fractures of the femoral neck, glides out as the fracture fragments telescope in the course of

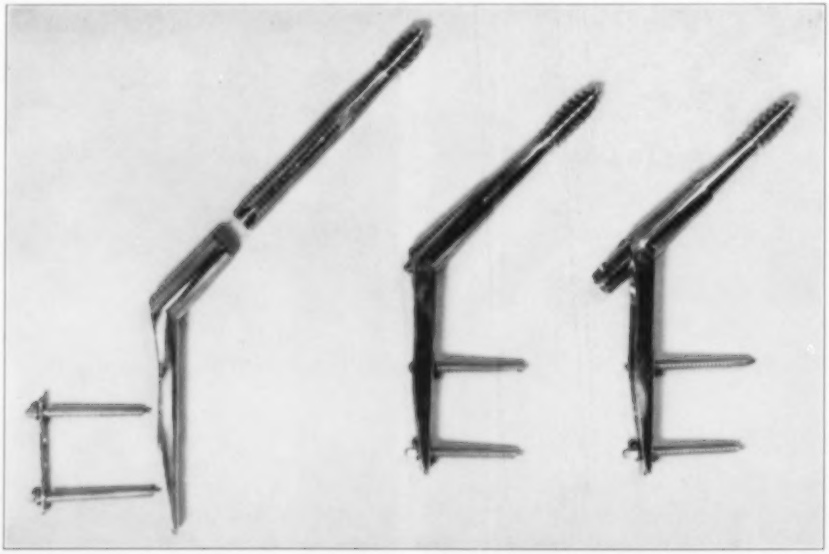

Fig. 1

Photographs of the gliding screw-plate: On the left, disassembled; center, in the correct position after operation; and on the right, after the screw has glided out of the cuff.

absorption. The new appliance takes into account any shortening from absorption which may take place at the fracture site (Figs. 2-A through 3-C). The screw-plate, made of stainless antimagnetic steel (V2A), consists of two parts: (1) the screw, the broad threads of which must be so few that they always end proximal to the fracture line, since otherwise they will hinder the gliding process, and (2) the plate, which is U-shaped for bending strength; at the upper end of the plate there is a cuff, fixed at an angle of 135 degrees, in which the screw glides. The junction between the cuff and the plate is so strong that bending to a greater extent or breaking are not possible. The screw cannot jam in the cuff. For routine operations a single angle is sufficient; only in special cases, such as fixation of a subtrochanteric osteotomy for pseudarthrosis of

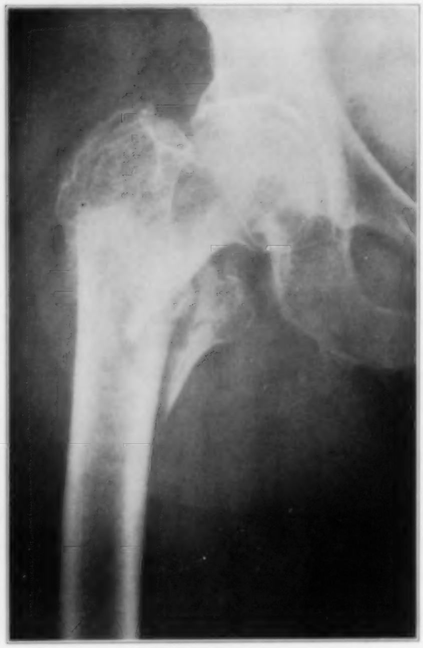

Fig. 2-A

Figs. 2-A to 2-C: Roentgenograms illustrating the mode of action of the screw-plate *in situ*.

Fig. 2-A: Roentgenogram made on admission, showing the position of the pertrochanteric fracture.

Fig. 2-B: Roentgenogram made after reduction and internal fixation, showing the position of the screw-plate.

Fig. 2-C: Roentgenogram made two weeks after operation. Full weight-bearing had been started, the fracture fragments had begun to telescope, and the screw has consequently glided out of the cuff.

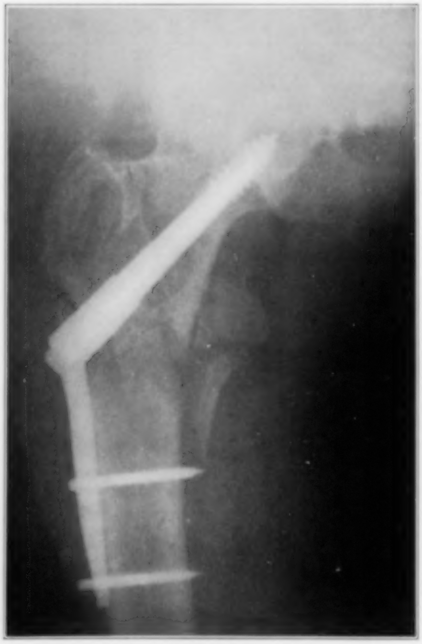

Fig. 2-B

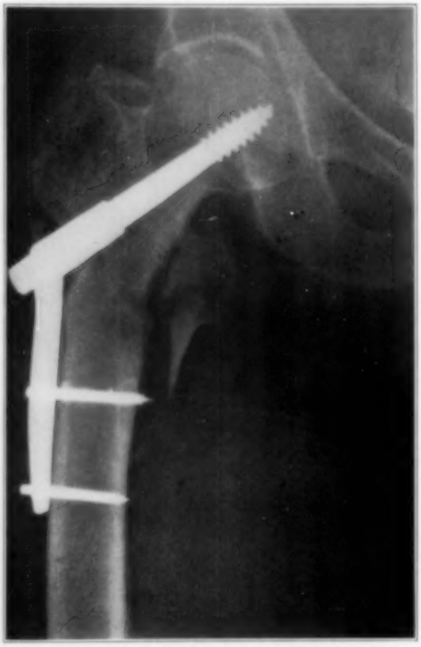

Fig. 2-C

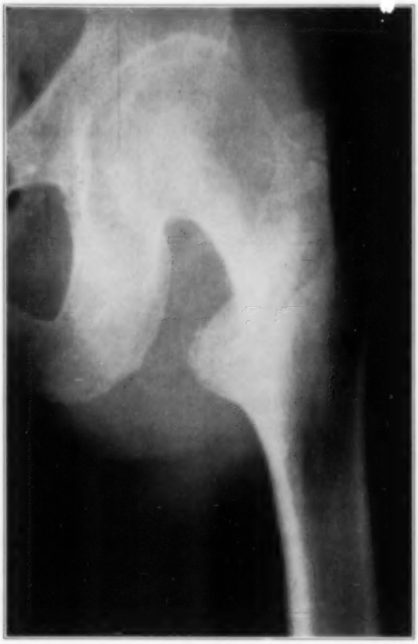

FIG. 3-A

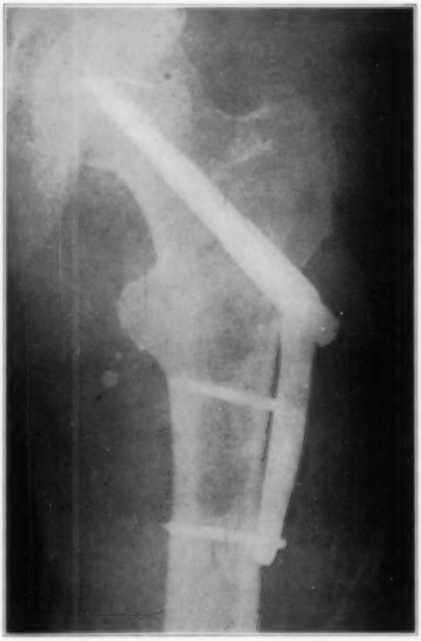

FIG. 3-B

Roentgenograms illustrating the use of the screw-plate in a cervicotrochanteric type of fracture.

Fig. 3-A: Roentgenogram showing the position of the fracture on admission.

Fig. 3-B: Roentgenogram showing the position of the screw-plate after reduction and internal fixation.

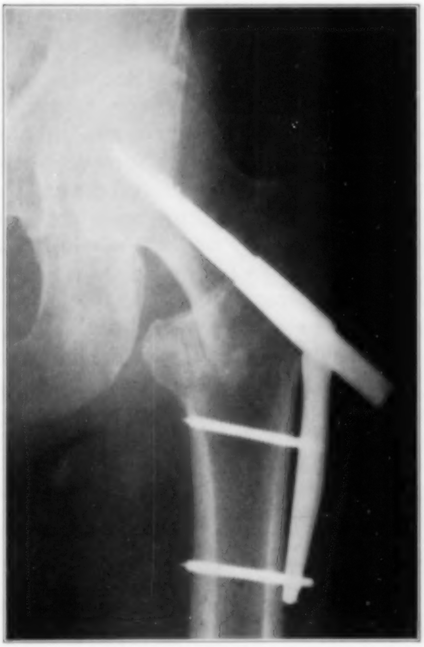

FIG. 3-C

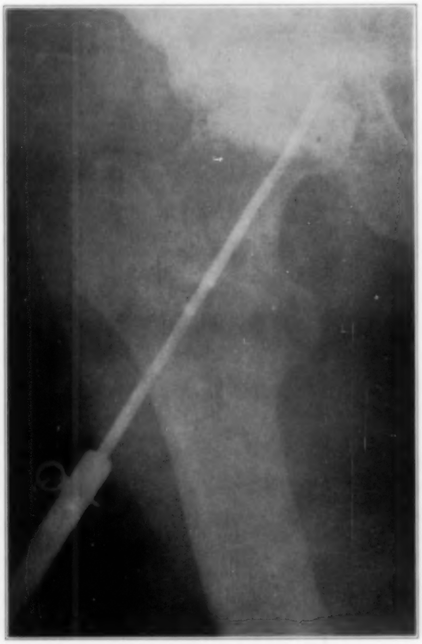

FIG. 4

Fig. 3-C: Roentgenogram made two weeks later. In this case, telescoping of the fracture fragments had been quite exceptional.

Fig. 4: Roentgenogram showing the pin in the best position for acting as a guide.

TABLE I

RANGE OF HIP AND KNEE MOTION

	Range of Hip Motion					Knee Flexion (*No. of Patients*)
	Flexion (*No. of Patients*)	Abduction (*No. of Patients*)	Adduction (*No. of Patients*)	External Rotation (*No. of Patients*)	Internal Rotation (*No. of Patients*)	
No restriction	10	5	11	9	2	9
Restricted by:						
0–10 degrees	1	3	1	1	6	1
10–20 degrees	1	4			3	1
20–30 degrees				2	1	
30–40 degrees						
40–50 degrees						1

the femoral neck, have we ordered a plate with the cuff fixed at a more acute angle. In order that the principle of gliding may also be applied in cases of subtrochanteric fracture, the holes through which the screws holding the plate to the femoral shaft are inserted are oblong. For pertrochanteric fractures two screws suffice; for subtrochanteric fractures the plate must be longer and three screws are needed. The screws are inserted at the lower end of the opening and are joined to each other by a small flat plate gliding in the U-shaped plate. By this contrivance the latter may glide downward when the fragments of the subtrochanteric fracture telescope.

Any force acting on the femoral head in the direction of the body axis will be diverted by the gliding screw into the direction of the axis of the screw, so that it strikes the fracture line approximately at a right angle and acts not as a shearing but as a compressing force—that is, in the most favorable way.

TECHNIQUE OF OPERATION

The fracture is reduced by traction on the operating table. An incision similar to that used for the insertion of a nail-plate is then made. As a pilot for the screw we use an awl-like pin (Fig. 4). This is inserted through a small hole drilled in the lateral cortex of the shaft at a point which has been exactly calculated from the roentgenograms made after reduction and is then driven forward, the surgeon feeling his way along the relatively compact distal cortex of the femoral neck. When the pin is *in situ*, a canal for the screw is made with a drill provided with a central hole which follows the course of the pilot pin. The pin is then removed, the grooves are cut, and the screw is inserted. With a special instrument a bed is cut for the cuff in the cortex around the screw, the cuff is slipped into place, and the plate, which now lies close to the femoral shaft, is fixed to the latter with small screws which should just penetrate the opposite cortex. If the plate projects somewhat from the shaft, the angle between the cuff and the plate can be altered by a few degrees.

It is advisable to make control roentgenograms after insertion of the pilot pin, after insertion of the screw, and before ultimate closure of the wound.

POSTOPERATIVE TREATMENT

We require the patient to stand once a day, beginning with the first postoperative day, to achieve impaction. Exercises in bed are begun on the second to the fourth day and ambulation with full weight-bearing is begun as soon as the patient can tolerate it. Often we have great difficulty in persuading patients, particularly aged females, to leave their beds, but it is of vital importance to succeed in this point. Lately we have proceeded in cases of subtrochanteric fractures just as we do in pertrochanteric fractures if at operation the osteosynthesis is found to be stable. When ambulation is first begun, we allow the patient to use forearm crutches or a walking stick to give him a sense of security. It must be stressed, however, that these aids are not intended to reduce the amount of early weight-bearing, which is necessary if the principle of gliding is to be applied to its full extent. The telescoping of the fracture fragments and the ensuing impaction stimulate the formation of callus and thereby accelerate the process of healing, a fact which is generally recognized. Possibly the extent of absorption is increased by a few millimeters as a result of the early weight-bearing.

RESULTS

The number of cases in which we have used this method since we first adopted it in 1952 is twenty-eight. There were eighteen cases of pertrochanteric fracture, one subtrochanteric fracture, four cases in which there was both a subtrochanteric and a pertrochanteric fracture, and one lateral fracture of the femoral neck. We have also used this method in four cases for fixation of the fragments after a subtrochanteric osteotomy for pseudarthrosis of the femoral neck.

The mean age of the patients with fresh fractures was sixty-three years. There were four deaths (16.6 per cent.) and among the patients who died the mean age was 77.7 years. Of these, one patient died from cerebral embolism, one from pulmonary embolism, one from cardiac failure, and one from unknown reasons at home; these deaths occurred eight days, twenty-four days, one day, and five weeks after operation, respectively.

The average time of hospitalization was 48.5 days for patients with pertrochanteric fractures and fifty-eight days for those with subtrochanteric fractures; the shortest hospital stay was thirteen days and the longest, ninety-one days. Excluded from this calculation are the four patients who died and three patients with accompanying injuries which prolonged the hospitalization.

Three cases of infection occurred, in spite of the routine use of antibiotics. Of these, one was extensive; it occurred in a patient, eighty-seven years old, who died of pulmonary embolism.

We have not been spared some mishaps while working out the operative technique. However, we only twice saw complications of the type frequently encountered when the nail-plate is used. In both cases the outcome was a coxa vara. These case histories are of general interest, as they illustrate some mistakes which can occur:

One case was the first patient in whom the screw-plate was used. There was extensive cortical overlap in the region of the calcar femorale. The reduction at operation was excellent, but we now believe that the screw was too short and that it was placed in the center of the femoral neck. During the postoperative period, the proximal fragment tilted in a coxa vara position. Bony union ensued, with a coxa vara of 100 degrees.

In the other case the screw was overdriven and slipped *in toto* into the bone. During the attempt to extract it, the head of the screw was damaged by unavoidable forceful handling, so that the cuff could not be slipped over it. The screw had to be replaced, but after so much manipulation the cancellous bone of the slender femoral neck was loosened to such an extent that the new screw could not find a hold in a good position. It lay at the upper margin of the femoral neck and head and not at the angle calculated; the plate, therefore, projected from the femoral shaft. The plate was bent too far in order to make it fit, so that the screw jammed in the cuff and the gliding mechanism could not become effective. After the operation the screw cut upward, although weight-bearing in this case was begun only after ten weeks; the screw had begun to cut upward even before weight-bearing was begun. Bony union took place, with a coxa vara of 110 degrees.

In no case did non-union occur.

Before writing this report, we re-examined the twelve surviving patients with fresh fractures whose accidents had taken place more than six months earlier. The period of follow-up was seven to twenty-two months, with an average of thirteen months. The result in respect to the range of joint movement could be termed *good* in five patients (moderate limitation of one range of movement being present) and *fair* in seven patients (moderate limitation of two or more ranges of movement) (Table I). In no case did we feel that the result should be classified as poor. Knee movement was slightly restricted in two cases and considerably restricted in one; the latter patient was a man, thirty-four years old, lacking all drive.

Nine patients reported pain on the outer side of the thigh after strenuous exercise or when lying on the side of the fracture. Six patients reported insignificant and two, substantial restriction of their pre-accident activity. None was confined to the house.

We were somewhat alarmed when we observed that the quick telescoping of the fracture fragments sometimes resulted in a relative "lengthening" of the iliac muscles and therewith in a positive Trendelenburg sign. Fortunately, this phenomenon is later compensated. Twice we found a slightly positive Trendelenburg sign in two patients, seventy-six and eighty-two years of age, respectively, but this did not hinder the gait materially.

Use of the Screw-Plate in Subtrochanteric Osteotomy

The advantages of the gliding screw-plate in these cases are (1) that the three components—the femoral head, the intermediate piece, and the femoral shaft—are firmly attached to one another, so that there is no danger of displacement once the screw-plate is in place; (2) that full impaction acts to further the healing process at the site of the pseudarthrosis and of the osteotomy and that no shearing forces can act on the pseudarthrosis; and (3) that the period of recumbency can be shortened substantially.

DISCUSSION

The method of fixation of trochanteric fractures described here makes possible early ambulation with full weight-bearing and thereby shortens the length of stay in bed and in the hospital. At the same time the method avoids the complications commonly encountered when the nail-plate is used.

The operation, which need not take longer than the nailing of a fracture of the femoral neck, requires a trained team and adequate operating-room and roentgenographic facilities. The optimal position of the screw is with the shaft lying immediately above the distal cortex of the femoral neck and the tip lying in the lower part of the femoral head, where the cancellous bone is densest and the screw has the best hold. This is particularly important in comminuted fractures and in fractures with cortical overlap or cortical destruction in the region of the calcar femorale. The tip must be driven to within three to five millimeters of the articular margin, where it finds the firmest hold and is thus prevented from cutting upward. In the lateral aspect the screw should lie well centered.

Early weight-bearing is necessary for the gliding process to become fully effective, although some impaction and gliding-out of the screw take place even in recumbency. In postoperative roentgenograms the gradual gliding-out of the screw, particularly during the first few days, may be clearly seen.

We believe that it is not necessary to remove a screw which is lying in accurate position, particularly since the removal, as in the case of the nail-plate, is no minor procedure. The indication for removal may be present in lean patients, when the head of the screw protrudes too far out of the cuff and irritates overlying tissues.

NOTE: Since this paper was submitted, the number of cases in which the screw-plate has been applied has risen to seventy-three. The operative technique has remained the same and the observations on these additional forty-five patients have not necessitated any changes in the technique described or in the conclusions drawn. In subtrochanteric fractures caution is indicated as regards early weight-bearing.

THE RESECTION-ANGULATION OPERATION FOR HIP-JOINT DISABILITIES *

BY HENRY MILCH, M.D., NEW YORK, N. Y.

From the Second Orthopaedic Service, Hospital for Joint Diseases, New York

The surgical problem presented by disabilities of the hip has in the past been approached by a variety of methods which have ranged from arthrodesis to its direct opposite—arthroplasty or prosthetic replacement. It is generally admitted that these latter procedures have not proved to be the sought-for panacea and that they offer no assurance for the relief of pain or limitation of motion. While a successful arthrodesis does eliminate pain, it establishes irrevocably the very limitation of motion for which patients are willing to submit to orthopaedic operations. However, the procedure descriptively designated as the "resection-angulation operation" has yielded such definitive improvement both in the relief of pain and in the restoration of motion that it merits further consideration and study.

THE TWO-STAGE RESECTION-ANGULATION OPERATION

The resection-angulation operation was originally performed in two stages and was first reported in 1943[10]. In principle, the operation involves two separate procedures: (1) release of the pelvis and restoration of femoral *mobility* by the resection of the femoral head and neck and (2) the re-establishment of *stability* by means of a pelvic-support osteotomy of the type described by Schanz.

During the early development of the operation, before an adequate means of skeletal fixation had been devised, the operation was performed in two distinct stages. Since the restoration of mobility contra-indicated the use of a plaster spica and the osteotomy absolutely indicated its need, it became important to determine the order of succession of the two stages. Experience quickly demonstrated that the primary resection of the femoral head necessitated a prolonged period of traction to prevent upward dislocation of the shaft and that the immobilization subsequently necessary to secure union of the osteotomized femur resulted in a marked restriction of the range of motion previously obtained. This method was therefore quickly abandoned **.

On the other hand, while the primary osteotomy of the femoral shaft obviated the necessity for immobilization, it rendered resection of the femoral head and neck technically more difficult. Nevertheless, the immediate postoperative care, as well as the end results, showed such definite superiority of the latter technique over the former that the latter was employed in preference to primary resection of the femoral head.

Two of the patients who had been treated by this two-stage procedure became available for check-up examination and showed eminently satisfactory results (Table III, Cases 1 and 33).

THE ONE-STAGE RESECTION-ANGULATION OPERATION

Following the description of the Blount-Moore blade-plate, the technique of the operation was modified so as to permit completion in a single stage. This one-stage operation was subsequently reported in a number of communications [12,13,14,15,16,17,18]. The technique was developed following a series of studies on the pelvifemoral angle [9], the postosteotomy angle [11], and the relative merits of the Schanz and Lorenz osteotomies [7,8].

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** The two-stage method has, however, again been recommended by Batchelor [1,2,3]. His "pseudarthrosis operation" is a modification of Girdlestone's original procedure by the addition of a subtrochanteric osteotomy, performed as late as five or six weeks after the primary resection.

Although the procedure was developed with reference to the general problem of the arthrosis, it is noteworthy that, in 1950, a practically identical procedure was reported by Gruca [6]. This was a modification of an operation, reported in 1946 [5], which was used specifically in the treatment of tuberculous coxitis. It is interesting that the patient reported as Case 33, who was operated upon in 1937 by the two-stage method, had tuberculosis of the femoral neck. The site of the disease could only be removed by the resection of the neck. In those patients in whom the chemotherapeutic attack on the tuberculous lesion has been unsuccessful and in all patients in whom there has been irremediable tuberculous destruction of the joint surface, the resection-angulation operation appears to be specifically indicated.

THE POSTOSTEOTOMY ANGLE

While the operative procedure is not technically difficult, its proper performance is dependent upon the careful preoperative determination of the angle to which the distal fragment of the osteotomized femur should be and may be abducted after the resection of the femoral head (the postosteotomy angle). Since, in the erect position, the osteotomized and angulated femur must rest with its inner side against the lateral wall of the pelvis, it is clear that the postosteotomy angle must be made congruent with the angle of inclination of the lateral pelvic wall. If the postosteotomy angle is greater than the angle of inclination of the pelvic wall, limitation of motion, excessive ipsilateral downward tilting of the pelvis, and, consequently, relative shortening of the contralateral limb will result [19]. If, on the contrary, the postosteotomy angle is made insufficiently large, ipsilateral tilting of the pelvis is discouraged, stability is impaired, and disparity in limb length remains uncorrected.

It must, therefore, be recognized that maximum stability, without concomitant impairment of hip mobility, can only be assured if the subtrochanteric osteotomy is so performed that, with the extremities erect and parallel, the postosteotomy angle does not exceed the critical angle determined by the inclination of the pelvic wall. The normal inclination of the pelvic wall with the pelvis level is remarkably constant — between 205 and 210 degrees. (In congenital dislocations of the hip, the angle of the inclination of the pelvic wall may be reduced to as low as 190 degrees. Its determination is of fundamental importance and is absolutely essential for the proper performance of *any* pelvic-support osteotomy in the subtrochanteric region.)

R. A. Milch has recently studied the anteroposterior roentgenograms (target distance, ± 40 inches) of 100 normal male and 100 normal female pelves and has shown that, under these circumstances, normal male pelves were characterized by a mean *interacetabular* distance of 25.9 ± 1.7 centimeters, and female pelves by a mean *interacetabular* distance of 24.0 ± 1.6 centimeters. The mean angle of inclination of the lateral pelvic wall in the male subjects was 211.4 ± 5.8 degrees and in the female subjects was 206.4 ± 4.7 degrees. In each instance the difference between male and female subjects was statistically highly significant.

The importance of these observations lies in the fact that while resection of the femoral head and neck involves an actual shortening of the limb, the angulation osteotomy enforces pelvic tilt and thus results in an apparent compensatory lengthening of the limb [20].

PREOPERATIVE PREPARATION OF THE BLADE-PLATE

In the actual preparation of the patient for the operation, a tracing of the anteroposterior roentgenogram of the pelvis is made for the purpose of determining, as a basic measure, the angle of inclination of the lateral pelvic wall. This establishes the minimum angulation of the distal portion of the osteotomized femoral shaft consonant with maximum stability and minimum limitation of motion.

The site of the projected femoral osteotomy, usually at the level of the lower margin of the ischial tuberosity is marked, and, at this point, an angle is constructed between the upper and lower portions of the femur to be osteotomized which is equal to the angle of inclination of the lateral pelvic wall. As a means of checking this, a tracing of the femur as it will appear after the resection of the femoral head and neck is made. The tracing of the femur is cut at the site of the projected osteotomy so that the angle formed by the *inner* aspect of the osteotomized femur is congruent with the angle of inclination of the lateral pelvic wall when the femoral shaft is held perpendicular to the level pelvis. Because of a difference in the contour of the lateral and medial aspects of the osteotomized femur, the projected position of the immobilizing blade-plate is marked on the outer side of the tracing of the femur. This is used as the guide for the angulation of the blade-plate. The necessity for roentgenographic control in the operating room is thus completely eliminated.

The blade-plate which at present is being used is Z-shaped (Fig. 1). The upper 3.8 centimeters (one and a half inches) is curved on the flat so as to permit easy introduction into the trochanteric region. The straight portion, about 3.8 centimeters in length, assures a generally satisfactory level for the osteotomy when the blade is inserted at, or slightly below, the base of the greater trochanter. The lower portion of the plate, angulated outward to the predetermined degree, has three or four screw holes for the placing of screws in order to afford firm fixation of the distal fragment of the osteotomized femur.

Since the upper limit of the tilt of the pelvis is only 20 to 25 degrees, the degree to which the postosteotomy angle may be permitted to exceed the determined angulation of the lateral pelvic wall should not be greater than 15 to 20 degrees. When the osteotomy is designed to compensate for an existing disparity in limb length, correction up to about five centimeters (two inches) may be obtained in this manner. If the disparity exceeds five or 6.3 centimeters (two or two and a half inches), correction must be obtained by the elevation of the shoe, rather than by an increase in the angle of abduction of the distal fragment of the osteotomized femur [19].

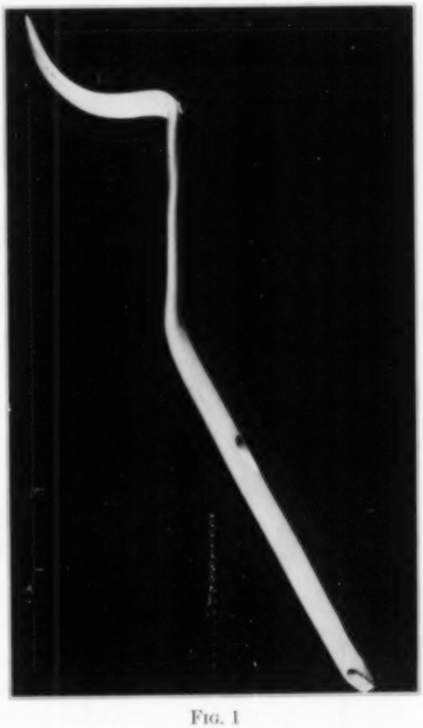

FIG. 1

Modified Blount-Moore blade-plate.

SURGICAL TECHNIQUE

The surgical approach is made through a lateral iliofemoral incision and extends from the anterior superior spine of the ilium to the base of the trochanter and downward along the lateral aspect of the femur. This affords a relatively avascular approach to both the femoral shaft and the hip joint, without severance of muscle attachments. That the nerve to the tensor fasciae latae is thereby sacrificed seems to be more than compensated for by the increased visibility of all but the most inferior portions of the hip joint. After reflection of the subcutaneous tissues, the deep fascia is incised in the line of the skin incision. The circumflex vessels are ligated at the base of the trochanter, and the intermuscular space between the tensor fasciae latae and the glutaeus medius is bluntly opened. Upon retraction of these muscles, the superior, anterior, and posterior aspects of the capsule are visualized.

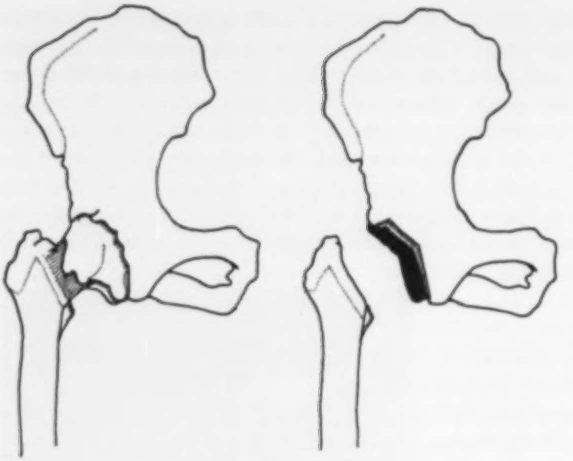

Fig. 2

Schematic drawings showing the appearance of the hip before and after the resection of the femoral head and neck.

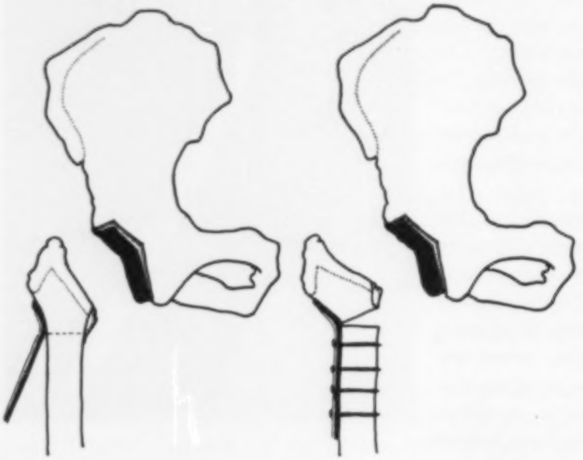

Fig. 3

Schematic drawings showing the osteotomy of the femur and the fixation of the osteotomized fragments with the angulated blade-plate.

The superior portion of the capsule is incised along its acetabular margin and it is turned down as a flap. The femoral head is then dislocated, if necessary after the preliminary resection of the osteophytic excrescences about the acetabular margin. The neck is transected along the intertrochanteric line (Fig. 2), injury to the attachment of the iliopsoas muscle being carefully avoided, and the capsular flap is sutured over the raw area at the base of the neck. The muscles are then reapproximated.

The upper end of the femoral shaft is exposed, and the blade-plate is inserted so that the apex of the angle of the plate, which was computed prior to operation, lies at the predetermined level of the osteotomy. Drill holes are made at this level in order to avoid splintering of the bone; the femoral shaft is transected. The distal fragment is abducted, is internally rotated about 20 to 25 degrees, and is held against the plate with Lowman clamps until it has been securely fixed with screws of adequate length (Fig. 3). The wound is then closed in layers without drainage, and a compression dressing is applied. Immobilization in a plaster mold is specifically avoided.

POSTOPERATIVE CARE

Postoperative care is of the utmost importance. It is, indeed, not an exaggeration to insist that the ultimate result is almost entirely dependent upon the meticulous attention to the postoperative course. The operation merely establishes the mechanical possibility of passive motion. While this in itself is extremely significant in that it permits sitting down and the putting on of shoes and stockings, it is still not quite sufficient. The ability to walk upstairs normally presupposes the power of actively flexing the thigh so that the foot can be advanced to the next step above. The degree to which this can be achieved will, of course, depend upon the residual power in the hip muscles. Despite the atrophy and fibrosis which may be expected in long unused muscles, the degree to which they may be reactivated by careful re-education is frequently quite startling.

There are, however, other factors to be considered. The pelvitrochanteric muscles are necessarily traumatized and are suffused with blood which becomes organized during the immediate postoperative period. In addition, and as a consequence of the removal of the head and neck of the femur, the pelvitrochanteric muscles become relatively lengthened and tend to contract and to adjust to the newly established mechanical conditions. Unless constant attention is directed to its avoidance, contracture will occur in whatever position the limb is fixed.

Since flexion is fundamentally necessary for the patient, the limb operated upon is suspended at right angles in balanced traction immediately upon return from the operating room. The opposite danger, limitation of extension by flexion contracture, is obviated by intermittent active and passive extension as soon as the postoperative reaction has subsided. It is usually possible, within one or two weeks, to have the patient sit up with his legs dangling. With the foot of the affected limb on a support, the patient is encouraged to bend forward, as if to tie his shoes. Within three weeks, unless the patient is excessively obese, walking with the aid of crutches is possible and is encouraged. Thereafter, exercises designed to increase the power of the pelvic muscles are instituted. Passive flexion is easily achieved, but active flexion, even to 90 degrees, is gained slowly. Experience has repeatedly demonstrated that a satisfactory range of motion at the time of the patient's discharge from the hospital may be subsequently reduced, or even lost because of the patient's disinclination to continue exercising. Exercising must be insisted upon until the danger of contracture has passed.

COMPLICATIONS

Surprisingly few complications have been encountered. Of the six deaths, three occurred more than a year after the operation, and a fourth was the result of a recurrent lymphosarcoma which the patient was known to have had for over nine years. The fifth death resulted from serum hepatitis four months after operation. The sixth death alone was *directly* attributable to the operation and occurred despite adequate and vigorous chemotherapy in a seriously debilitated, bed-ridden youngster, suffering from Still's disease.

Wound infections occurred in three other patients. These required extensive surgical débridement with removal of the blade-plate. In these patients there was an increase in the length of hospitalization and a decrease in the functional result.

Two patients with peroneal palsy recovered completely without any untoward sequelae. In one patient, normal convalescence occurred despite fracture of the blade-plate, and, in one other patient, replacement of the blade-plate occasioned only a slight retardation in functional rehabilitation. In one patient, a partially successful effort at the removal of excessive callus was undertaken, and in two other patients the removal of excessively long screws led to the immediate relief of pain (Table I).

Excessive Postosteotomy Angle

In at least three patients, an excessively large postosteotomy angle appeared to be responsible for postoperative pain. When the spine and contralateral hip are freely movable, an excessive postosteotomy angle will cause discomfort and some limitation of motion. This can be minimized by elevating the shoe on the contralateral extremity and by forcing an increase in the inclination of the lateral pelvic wall on the affected side. When the lumbosacral joint is so fixed that pelvic inclination is impossible, surgical revision of the postosteotomy angle is required.

Genu Valgum

Equally distressing is the apparent genu valgum and pain which seemed to be characteristic in all patients who had had abduction osteotomies in the subtrochanteric region. The sudden appearance of genu valgum only a short time after operation did not seem to be explicable on the basis of any actual axial alignment. When these patients were re-examined, it was noted that there was a definite tendency toward external rotation of the limb. When the patella was rotated internally, the genu valgum was seen to be apparent and was caused by the prominence of the medial femoral condyle. This was due to the fact that the proximal fragment rotated externally as it lay against the sloping side of the pelvis. The apparent genu valgum and the consequent strain on the tibial collateral ligament could be minimized by rotating the distal fragment of the femur internally before abducting it and affixing the blade-plate to it.

Limp

Some have considered the limp which inevitably attends the performance of this operation a serious drawback. This would not seem to be a serious objection, since the patients all had a limp before the operation. The limp is, in itself, not a sufficient indication for operation. It is interesting to note that in a few patients, particularly those operated upon unilaterally, the limp was barely apparent and, when present,

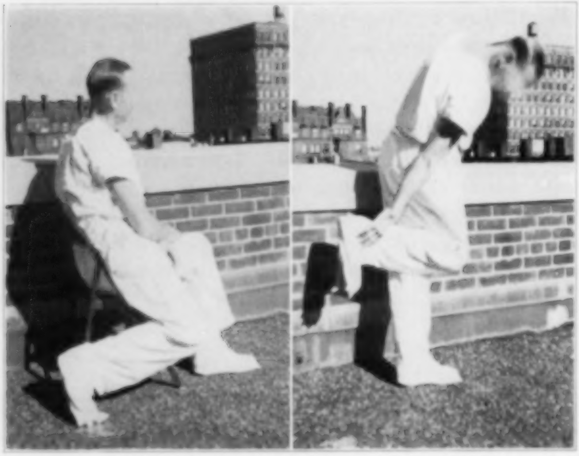

Fig. 4-A

Case 12. G.S. Photographs made in December 1948. The patient was unable to sit normally or to put on his shoes in a normal manner (he put them on backward).

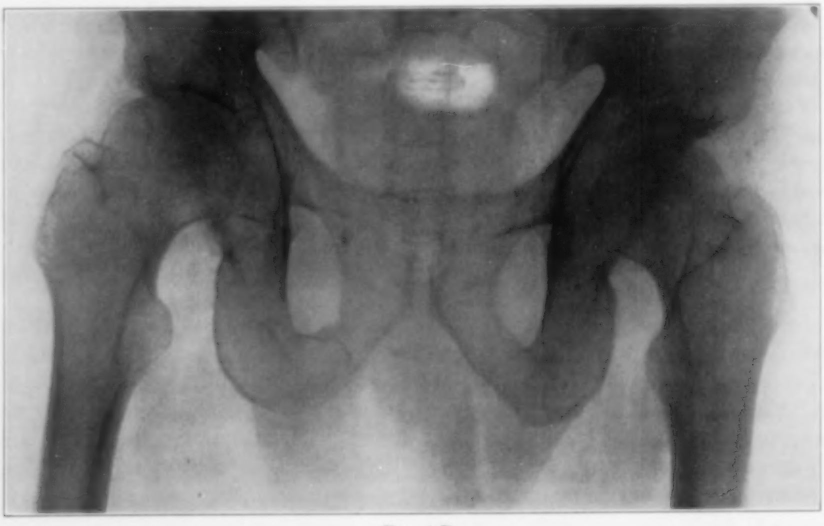

Fig. 4-B

Roentgenogram made in December 1948. The joint space was narrowed and the head showed the lipping at its lower margin characteristically seen in osteo-arthritis of the hip.

could be minimized by elevating the shoe on the affected side. It was observed, moreover, that the limp appeared to be more marked in those patients in whom there had been incomplete extension of the hip after the operation. This suggested the likelihood that the limp was due not to instability but to actual shortening caused by the excision of the head and to the apparent shortening due to varying degrees of flexion contracture. Failure to note the existence of flexion contracture has undoubtedly been responsible for the erroneous conclusion noted by some observers that the Trendelenburg sign was present. It is evident that, in the presence of a flexion contracture, this test loses much of its value.

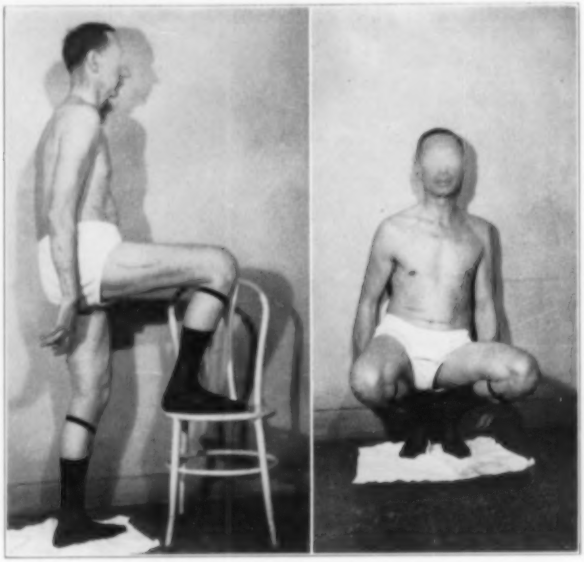

FIG. 4-C

Photographs made three years after operation.

EVALUATION OF RESULTS

The present review embraces the records of fifty-six patients in whom sixty-four resection-angulation operations were performed. Table II indicates the underlying etiology.

For many operative procedures, it is possible to establish definite standards by which surgical success or failure may be readily gauged. In the hip joint this is difficult because of the many different factors which must be taken into consideration. It is impossible to employ any of the standard criteria which use the normal hip for comparison. Whether the gait is aesthetically pleasing or whether the roentgenograms present an ideal appearance is a matter of little importance. For purposes of comparison, it it is equally unsatisfactory to estimate the functional capacity of the hip by a summation of the range possible about each axis of motion. Apart from the fact that the method usually employed of measuring hip flexion is inaccurate [9] and is totally inapplicable

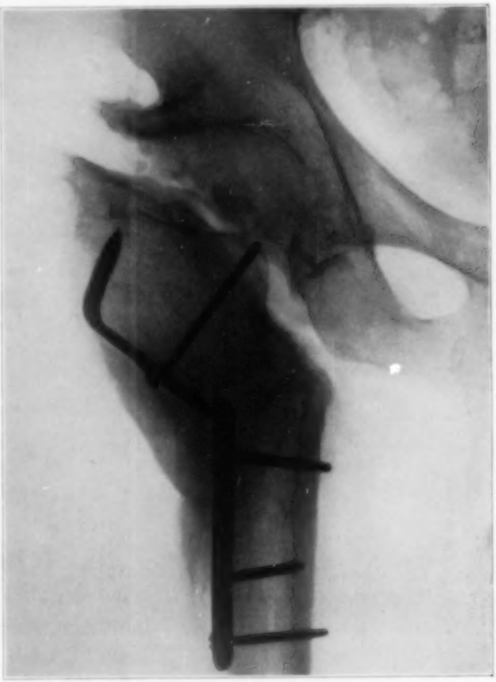

FIG. 4-D

Fig. 4-D: Roentgenogram made in December 1953, sixty months after the resection-angulation operation. Despite fracture of the blade-plate at the site of angulation, solid healing resulted.

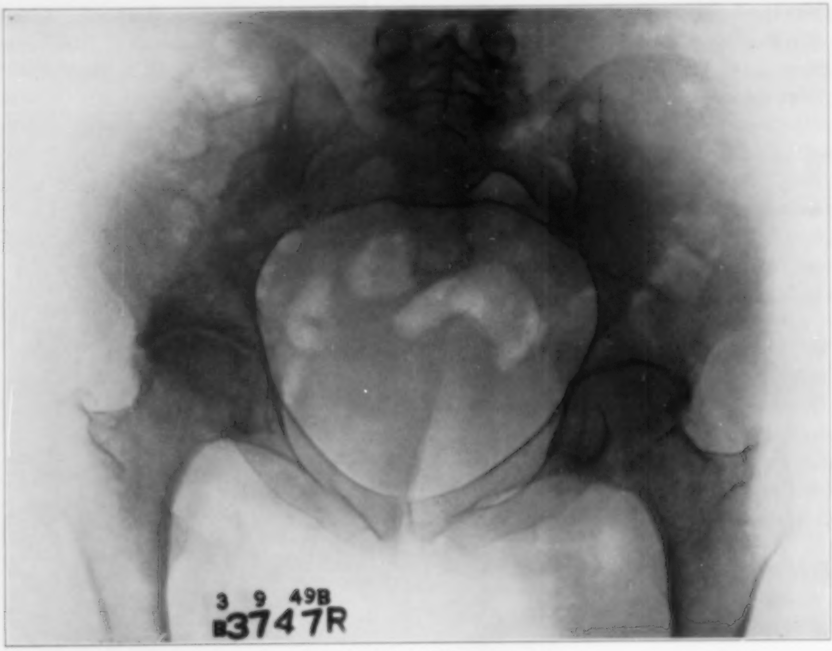

Fig. 5-A

Case 28. D.B. Roentgenogram made in March 1949. There was bilateral ankylosing arthritis of both hips.

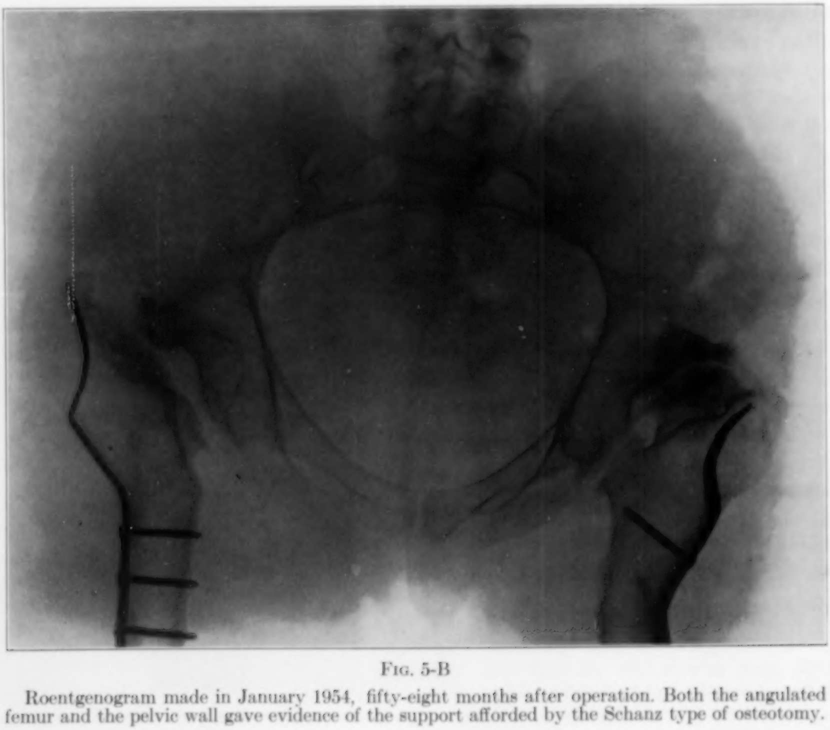

Fig. 5-B

Roentgenogram made in January 1954, fifty-eight months after operation. Both the angulated femur and the pelvic wall gave evidence of the support afforded by the Schanz type of osteotomy.

TABLE I

COMPLICATIONS

Complication	No. of Patients		
Deaths			6
Not attributable to operation		4	
Coronary arterial disease	1		
Unknown cause (nineteen months after operation)	1		
Malignant disease	2		
Attributable to operation		2	
Serum hepatitis (due to blood transfusion, four months postoperatively)	1		
Sepsis	1		
Wound infections			3
Peroneal palsy (transient)			2
Unsatisfactory fixation			7
Pulling out of the blade-plate		2	
Fracture of the blade-plate		2	
Excessive screw length		3	
Excessive callus formation			4
Excessive postosteotomy angle			3

in the presence of associated fixation of the spine or of the contralateral hip, it is obvious that an increment in the range of abduction or rotation is far less significant to the patient than an even smaller increase in flexion. Total loss of rotation imposes a disability which is of relatively slight functional significance as compared with loss of abduction. On the other hand, loss of flexion to less than 90 degrees may be markedly disabling.

In the clinical determination of operative results in hip-joint disease, it is of the utmost importance to give greater weight to the restoration of flexion than to that of rotation or even of abduction.

Similarly, it is quite impossible to use the ability to work as a yardstick in a patient who has not worked or who has been bed-ridden for any length of time. In arthritic patients, it is seldom that a single hip is involved. More frequently, multiple joint involvement tends to mask, if not entirely to vitiate, what might otherwise be considered an excellent result in a single hip.

As a consequence of age or of prolonged disability, the muscles in these patients are poor, and return of active motion is necessarily long delayed. In addition, these patients frequently suffer from circulatory disease, or other chronic disease, which compounds the normal difficulties presented by the local condition. They are debilitated, often obese, and frequently lack the ability or desire to cooperate in the necessarily trying postoperative care.

TABLE II

ETIOLOGY

(Fifty-six Patients and Sixty-three Resection-Angulation Procedures)

Condition	No. of Cases	Condition	No. of Cases
Osteo-arthritis	15	Congenital dysplasia	2
Ununited fracture	7	Tuberculosis	2
Rheumatoid arthritis	7	"Arthritis"	1
Old epiphysiolysis	6	Charcot joint	1
Aseptic necrosis	3	Otto pelvis	1
Congenital dislocation	3	Still's disease	1
Marie-Strümpell disease	3	Traumatic dislocation	1
Old pyarthrosis	3		

TABLE III *

SUMMARY OF CASES

Diagnosis	Age (*Years*)	Sex	Time Ambulation Was Allowed (*Weeks*)	Followed (*Months*)	Hip Pain	A.G.F. (*Deg.*)	A.G.E. (*Deg.*)	Abduction (*Deg.*)	Adduction (*Deg.*)
Primary Unilateral Hip-Joint Disease									
1. Aseptic necrosis	27	M		210	None	90	180	20	10
2. Aseptic necrosis	21	M	3	11	None	60	180	35	20
3. Congenital dysplasia	35	F	3	23	Minimal	85	180	45	15
4. Epiphysiolysis (old)	51	F	8	7	None	135	180	20	5
5. Osteo-arthritis	65	M	12	17	Moderate	125	140	10	10
6. Traumatic arthritis	26	F	3	5	Moderate	90	180	35	0
7. Marie-Strümpell disease	28	M	12	60	Mild	50	170	15	0
8. Osteo-arthritis	65	M	20	42	Moderate	160	180	Slight	Slight
9. Osteo-arthritis	35	F	4	12	None	90	180	35	25
10. Pyarthrosis (old)	16	F	6	61	Minimal	100	180	40	0
11. Tuberculosis	10	F	4	47	None	35	180	50	25
12. Osteo-arthritis	45	M	4	60	None	50	165	35	0
13. Epiphysiolysis (old)	24	M	3	11	None	50	180	35	20
14. Ununited fracture	69	F	6	12	None				
15. Osteo-arthritis	45	F	4	37	Minimal	115	175	35	30
Primary Bilateral Hip-Joint Disease									
16. Rheumatoid arthritis	28	F	6	42	Minimal	120	180	25	15
17. Otto pelvis	35	F	7	10	None	40	145	30	30
18. Rheumatoid arthritis	60	F	4	35	Moderate	100	165	20	20
19. Epiphysiolysis (old)	26	F	4	17	None	90	170	20	30
20. Rheumatoid arthritis	66	M	5	8	None	55	180	25	20
21. Osteo-arthritis	59	F	8	49	None	90	175	20	20
22. Osteo-arthritis	65	F	8	37	Moderate	90	180	10	0
23. Congenital dislocation	45	M	3	57	None	90	180		
24. Rheumatoid arthritis	21	M	3	4	None	115	180	20	−15
25. Congenital dislocation	40	F	8	28	None	60	180	25	0

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* A.G.F. is angle of greatest flexion; A.G.E. is angle of greatest extension. In the columns headed "Put on Shoes" and "Sit" the *N* refers to the patient's ability to do so in a normal manner and the *D* denotes that the patient has difficulty in doing so.

TABLE III

Summary of Cases

Internal Rotation (*Deg.*)	External Rotation (*Deg.*)	Change in Flexion (*Deg.*)	Sit	Put on Shoes	Remarks	Evaluation	
						Pain	Motion
and Unilateral Operation (1° U.U.)							
0	10	60	N	N	Plaster immobilization.	Good	Good
25	15	40	N	N		Good	Good
10	10	20	N	N	Excessive postosteotomy angle.	Good	Good
0	0	15	D	D	Neglected postosteotomy care.	Good	Improved
0	30	15	D	D	Patient uses cane; marked obesity.	Unimproved	Improved
10	30	60	N	N	Excessive screw length.	Improved	Good
0	0	110	N	N	Plaster immobilization.	Improved	Good
Slight	0	−10	D	D	Infection; peroneal palsy; patient uses crutches.	Improved	Worse
10	10	20	N	N		Good	Good
15	20	20	N	D	Pain on weather change; slight difficulty with shoes; excessive screw length.	Good	Improved
30	30	80	N	N		Good	Good
0	45	60	N	N	Fractured blade-plate.	Good	Good
20	15	60	N	N	Patient uses cane.	Good	Good
			N	Unable	Marked obesity.	Good	Improved
15	10	60	N	N	Hip slightly unstable; arthritis of the ipsilateral knee.	Improved	Improved
and Unilateral Operation (1° B.U.)							
5	5	60	D	D	Polyarticular disease; excessive postosteotomy angle; *opposite* hip and knee fused.	Improved	Improved
20	65	85	N	N	Pain and limitation of motion of *opposite* hip.	Good	Good
0	0	65	N	D	Polyarticular disease.	Improved	Improved
5	10	80	N	N	Opposite hip previously arthrodesed. Patient recently readmitted for resection-angulation operation on this *opposite* hip.	Good	Good
20	30	55	N	N	Patient uses cane.	Good	Good
15	5	60	N	D	Pain and limitation of motion of *opposite* hip.	Good	Good
0	0	70	N	N	Infection; patient uses crutch.	Improved	Good
		60	N	N	Patient uses cane; *opposite* hip arthrodesed and painful.	Good	Good
0	0	20	N	N	Slight pain in spine.	Good	Improved
20	10	90	N	N	Patient uses crutch; pain and limitation of motion of *opposite* hip; moderate pain in knee and spine.	Good	Good

TABLE III (*continued*)

Diagnosis	Age (*Years*)	Sex	Time Ambulation Was Allowed (*Weeks*)	Followed (*Months*)	Hip Pain	A.G.F. (*Deg.*)	A.G.E. (*Deg.*)	Abduction (*Deg.*)	Adduction (*Deg.*)
26. Osteo-arthritis	59	M	12	22	None	140	170	10	10
27. Osteo-arthritis	71	M	15	5	None	145	180	15	0
						Primary Bilateral Hip-Joint Disease			
28. Rheumatoid arthritis	38	F	12 (R)	58	None	85	150	15	0
			(L)	56	None	100	160	15	0
29. Still's disease	18	F	0 (R)	4	None	110	180		
			(L)	1	None	130	180		
30. Marie-Strümpell disease	24	M	20 (R)	61	Moderate	130	180	10	5
			(L)	56	Moderate	140	180	10	40
31. Marie-Strümpell disease	35	M	(R)	67	None	130	180	20	15
			(L)	75	None	130	180	20	10
32. Rheumatoid arthritis	19	F	48 (R)	39	Slight	100	120	15	20
			(L)	42	Slight	100	120	15	30
						Secondary Unilateral Hip-Joint Disease			
33. Tuberculosis	19	F		48	None	90	180		
34. Arthritis	38	F	4	5	None	60	180	15	10
35. Epiphysiolysis	15	M	6	36	None	95	175	50	10
36. Charcot joint	22	M	8	59	None	40	180	60	35
37. Non-united fracture	40	F	6	72	Moderate	90	180	35	30
38. Non-united fracture	57	F	6	3	None	85	180	20	10
39. Non-united fracture	77	F		8	None	100	150	0	0
40. Non-united fracture	44	F	4	13	Slight	90	170	40	45
41. Osteo-arthritis	63	M	6	45	None	100	160	45	20
42. Non-united fracture	43	M	4	42	None	90	180	50	40
43. Non-united fracture	68	F		12	None	40	180	45	25
44. Non-united fracture	64	M	6	71	None	45	160	20	20
45. Pyarthrosis (old)	25	F	5	39	Slight	50	165	30	15
46. Gonococcal arthritis	30	F	4	36	None	90	180	20	15

TABLE III (*continued*)

Internal Rotation (*Deg.*)	External Rotation (*Deg.*)	Change in Flexion (*Deg.*)	Sit	Put on Shoes	Remarks	Evaluation Pain	Evaluation Motion
0	0	0	D	D	Excessive callus	Good	Unimproved
10	10	5	D	D	Patient uses crutch; pain and limitation of motion of *opposite hip.*	Good	Unimproved
and Bilateral Operation (1° B.B.)							
0	10	65	N	N	Peroneal palsy.	Good	Good
0	10	60	N	N		Good	Good
		70	N	N	Infection; patient died of sepsis.	Good	Improved
		50				Good	Improved
0	30	40	D	D	Patient uses cane.	Improved	Improved
5	5	40	D	D		Improved	Improved
0	30	50	D	D	Patient uses cane.	Good	Improved
5	5	50	D	D		Good	Improved
15	10	20	D	D	Patient uses crutch; flexion contractures of both knees.	Improved	Unimproved
0	10	20	D	D		Improved	Unimproved
and Unilateral Operation (2° U.U.)							
		75	N	N	Previous plaster immobilization.	Good	Good
5	5	120	N	N	Previous arthrodesis; patient died of lymphosarcoma.	Good	Good
5	35	80	N	N	Hip was ankylosed after previous plaster immobilization.	Good	Good
45	40	0	N	N	Osteotomy and plaster immobilization	Good	Unimproved *
15	30	30	N	N	Patient uses cane. Previous obturator neurectomy and two Smith-Petersen nails.	Improved	Good
10	10	55	N	N	Patient used crutch. Previous Smith-Petersen nail; died from serum hepatitis.	Good	Good
0	0	0	D	D	Previous Smith-Petersen nail; patient died of carcinoma of uterus.	Good	Unimproved *
40	25	0	N	D	Previous Smith-Petersen nail and Judet arthroplasty.	Good	Unimproved *
0	15	10	N	N	Patient uses cane; previous Whitman operation; excessive callus formation.	Good	Improved
45	45	20	N	N	Previous Telson wire.	Good	Good
45	45	50	N	N	Patient uses cane; previous Smith-Petersen nail.	Good	Good
0	15	45	N	N	Patient uses cane; previous Smith-Petersen nail.	Good	Good
0	40	75	N	N	Previous incision and drainage.	Good	Good
10	10	65	N	N	Two previous Jaenichen prostheses.	Good	Good

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* Although the results in these patients were evaluated *good* clinically, there was so little improvement over the preoperative condition as far as motion is concerned that the results are classed *unimproved.*

TABLE III (*continued*)

Diagnosis	Age (*Years*)	Sex	Time Ambulation Was Allowed (*Weeks*)	Followed (*Months*)	Hip Pain	A.G.F. (*Deg.*)	A.G.E. (*Deg.*)	Abduction (*Deg.*)	Adduction (*Deg.*)
						Secondary Bilateral Hip-Joint Disease			
47. Osteo-arthritis	40	F	4	8	None	120	160	15	5
48. Osteo-arthritis	55	M	4	24	Moderate	45	170	40	15
49. Osteo-arthritis	60	M	4	47	Severe	120	145	20	5
50. Osteo-arthritis	70	M	16	10	None	120	180	15	0
51. Rheumatoid arthritis	56	M	4	13	Severe	75	175	25	5
52. Congenital dislocation	40	F	8	12	Slight	80	170	30	35
53. Congenital dysplasia	30	M	4	38	Severe	90	165	15	15
						Secondary Bilateral Hip-Joint Disease			
54. Osteo-arthritis	59	F	3	(R) 8	Slight	85	175	25	25
			3	(L) 6	Slight	90	175	30	25
55. Epiphysiolysis	19	M		(R) 43	None	90	180	30	30
				(L) 41	None	75	180	30	30
56. Epiphysiolysis	15	M	4	(R) 18	None	110	180	20	10
			3	(L) 16	None	110	180	20	10

The only reasonable criterion which may be applied to the evaluation of the results in these patients is that which is determined by the success of the procedure in relieving the conditions for which the patient was willing to submit to operation. The patient's only interests are the alleviation of pain and the restoration of the ability to perform necessary, fundamental acts which are dependent upon the power to flex and to extend the hip in the sagittal plane. This is primarily expressed in the ability to stand or to walk without excessive pain, to sit down normally, and to put on shoes and stockings without assistance. The patients in the present series have, therefore, been reviewed with particular attention to the relief of pain and to the range of flexion obtained in the hip operated upon.

This does not connote any estimate of the over-all result as far as the patient is concerned. This is illustrated by the patient in Case 25 in whom the result with respect to pain and motion in the hip (left) operated upon was good, but the patient refused operation on the opposite hip because of a feeling of insecurity in the left hip. It is even better illustrated by the patient in Case 29 in whom pain was eliminated and motion was improved, but the patient died because of infection. The results have been graded *good*,

TABLE III (*continued*)

Internal Rotation (*Deg.*)	External Rotation (*Deg.*)	Change in Flexion (*Deg.*)	Sit	Put on Shoes	Remarks	Evaluation	
						Pain	Motion
and Unilateral Operation (2° B.U.)							
?	5	0	D	D	Previous cup arthroplasty.	Good	Unimproved
10	5	35	N	N	Previous Jaenichen prosthesis; patient died of coronary arterial disease.	Improved	Good
−10	15	20	D	D	Patient uses cane; previous obturator neurectomy.	Unimproved	Improved
−10	45	30	D	D	Patient uses cane; previous bifurcation osteotomy.	Good	Improved
5	50	0	D	D	Patient uses crutches; previous obturator neurectomy; excellent range of motion; patient fell and fractured nail; pseudarthrosis developed.	Unimproved	Unimproved
5	5	85	D	D	Patient used cane; previous osteotomy; died nineteen months later, cause unknown.	Improved	Good
10	45	45	N	N	Patient uses cane; previous obturator neurectomy.	Unimproved	Good
and Bilateral Operation (2° B.B.)							
25	20	70	N	N	Patient uses cane; previous nylon Judet arthroplasties; has only slight difficulty.	Improved	Good
20	20	0	D	D		Improved	Improved
20	45	90	N	N	Previous fascial arthroplasties; pin tore out of the left hip.	Good	Good
20	45	105	N	N		Good	Good
10	10	70	N	D	Previous epiphyseal-plate resections; has only slight difficulty.	Good	Improved
10	10	70	N	D		Good	Improved

improved, *unimproved*, or *worse*. For pain, the term *good* denotes the absence of pain or its reduction to a tolerable minimum; *improved* indicates an amelioration of pain with respect to its severity before operation. For motion, *good* denotes the patient's ability to flex the hip either actively or passively to at least a right angle; *improved* indicates his ability to flex the hip to less than a right angle but more than was possible prior to the operation.

The follow-up observations have been made by different examiners. Although this is open to the criticism of diversity of approach, it has the merit of greater objectivity than may be occasionally exhibited by the proponent of any procedure. Although an analysis on the basis of etiology does not seem justifiable in so small a series, it was considered advisable to differentiate between patients (1) who were subjected primarily or secondarily to the resection-angulation operation, (2) who had involvement of one hip only, and (3) who were affected bilaterally, and who were operated upon on one or both sides (Table III). This differentiation, therefore, resulted in the establishment of six different categories:

1. Primary unilateral hip-joint disease and unilateral operation (1° U.U.);
2. Primary bilateral hip-joint disease and unilateral operation (1° B.U.);
3. Primary bilateral hip-joint disease with bilateral operation (1° B.B.);

TABLE IV

Evaluation of Results in Fifty-six Patients with Sixth-four Hip Operations

Type	Pain						Motion					
	Good		Improved		Unimproved		Good		Improved		Unimproved	
	(No. of Cases)	*(Per cent.)*	*(No. of Cases)*	*(Per cent.)*	*(No. of Cases)*	*(Per cent.)*	*(No. of Cases)*	*(Per cent.)*	*(No. of Cases)*	*(Per cent.)*	*(No. of Cases)*	*(Per cent.)*
1° U.U.[*]	10	66.7	4	26.6	1	6.7	9	60.	5	33.3	1	6.7
1° B.U.	9	75.	3	25.			7	58.3	3	25.	2	16.7
1° B.B. (5 patients)	6	60.	4	40.			2	20.	6	60.	2	20.
2° U.U.	13	92.9	1	7.1			10	71.4	1	7.2	3	21.4
2° B.U.	2	28.6	2	28.6	3	42.8	3	42.8	2	28.6	2	28.6
2° B.B. (3 patients)	4	66.7	2	33.3			3	50.	3	50.		
Total	44	68.7	16	25.	4	6.3	34	53.1	19	29.7	11	17.2
1° and 2° U.U.	23	79.3	5	17.3	1	3.4	19	65.5	6	20.7	4	13.8
1° and 2° B.U.	11	57.9	5	26.3	4	15.7	10	52.6	5	26.2	4	21.2
1° and 2° B.B.	10	62.5	6	37.5			5	31.2	9	56.3	2	12.5

[*] *1° U.U.*, primary unilateral hip disease and unilateral operation; *1° B.U.*, primary bilateral hip disease and unilateral operation; *1° B.B.*, primary bilateral hip disease and bilateral operation; *2° U.U.*, secondary unilateral hip disease with unilateral operation; *2° B.U.*, secondary bilateral hip disease with unilateral operation; *2° B.B.*, secondary bilateral hip disease and bilateral operation.

4. Secondary unilateral hip-joint disease with unilateral operation (2° U.U.);
5. Secondary bilateral hip-joint disease with unilateral operation (2° B.U.);
6. Secondary bilateral hip-joint disease with bilateral operation (2° B.B.).

It is realized that so small a series cannot yield statistical information of great significance. Nevertheless, such data may have value in indicating tendencies, if not factual percentual relationships.

Outstanding was the high percentage of cases in which relief of pain was achieved. In forty-four of sixty-four cases (68.7 per cent.), pain was either completely relieved or was reduced to a tolerable minimum. In an additional sixteen cases (25 per cent.), pain was markedly lessened. In only four cases (6.3 per cent.) was there no relief of pain.

As regards motion, thirty-four cases (53.1 per cent.) had satisfactory restoration of flexion and an additional nineteen cases (29.7 per cent.) showed improvement in the range of flexion. Ten patients (15.6 per cent.) were unimproved and one was definitely made worse. This is indicated in Table IV which was, except in two or three instances, composed from results of examinations performed in *May 1953*.

As might have been expected, the good results obtained in patients with unilateral involvement were better than the good results obtained in the group as a whole:

1. In patients with primary unilateral hip-joint disease with unilateral operation and in patients with secondary unilateral hip-joint disease with unilateral operation, good results in the *relief of pain* were obtained in 79.3 per cent. as compared with 68.7 per cent. for the group as a whole (Table IV).

2. In patients with primary unilateral hip-joint disease with unilateral operation and in patients with secondary unilateral involvement with unilateral operation, good results in the *restoration of motion* were obtained in 65.5 per cent. as compared with 53.1 per cent. for the series as a whole (Table IV).

In the group of patients with primary unilateral hip-joint disease and unilateral

Fig. 6-A: Case 44. Roentgenogram made in April 1948 after Smith-Petersen nailing for fracture of the femoral neck.

Fig. 6-B: Roentgenogram made in March 1954, fifty-nine months after resection-angulation operation.

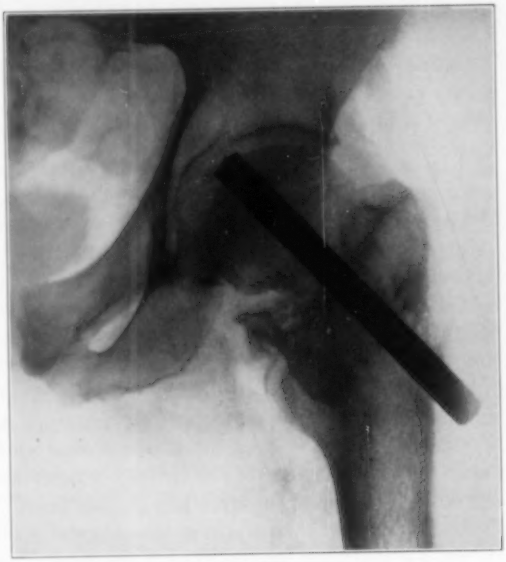

Fig. 6-A

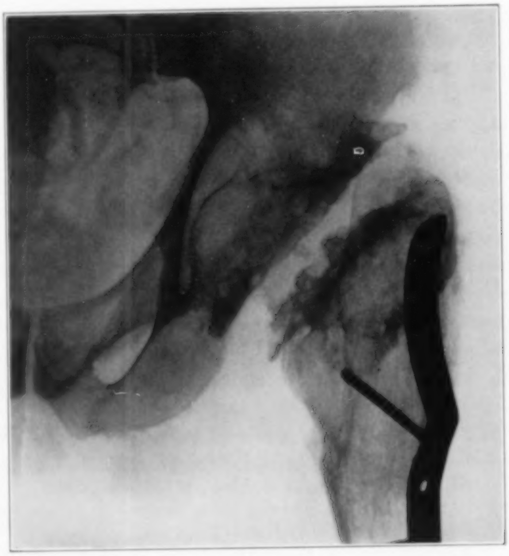

Fig. 6-B

operation, there was one patient with an ununited fracture of the femoral neck, while in the group with secondary unilateral hip-joint disease and unilateral operation, there were seven patients with non-union of fracture of the femoral neck. Of these seven, good results, as regards both pain and motion, were obtained in six. The percentage of good results in patients with secondary unilateral hip-joint disease and unilateral operation was considerably higher than that in patients with primary unilateral hip-joint disease and unilateral operation. This tends to establish the clinical observation that better results may be expected in patients with hip-joint involvement as a result of trauma than in patients with arthritis of the hip.

It should be noted that improvement as regards relief of pain was obtained in an almost unbelievably high percentage of patients (Table IV).

There was a marked difference in the percentage of good results as regards pain in twenty-one of thirty-five bilateral cases (1° B.U., 2° B.U., 1° B.B., and 2° B.B.) (60 per cent.) and as regards motion in fifteen of thirty-five bilateral cases when compared with the percentage of good results in the group as a whole (68.7 per cent. and 42.9 per cent.) or when compared with the percentage of good results in unilateral cases (79.3 per cent. and 65.5 per cent.). It is thought that an explanation for these differences is to be found in the hip *not* operated upon. Some confirmation for this belief is to be found in the fact that the percentage of good results in patients affected bilaterally with bilateral operation (62.5 per cent.) was definitely higher than that obtained in patients affected bilaterally with unilateral operation (57.9 per cent.). On the other hand, the percentage of good results as regards motion in patients affected bilaterally with bilateral operation was so low (31.2 per cent.) when compared with the percentage of good results in patients affected bilaterally with unilateral operation (52.6 per cent.) that two alternative conclusions must be considered.

1. That the suggested explanation is not in fact true;

2. That other factors, such as the involvement of the knees and spine, are of importance in the determination of the end results.

More data must be accumulated before any definite conclusions regarding these points can be made.

SUMMARY AND CONCLUSIONS

In a series of fifty-six patients, sixty-four resection-angulation operations were performed. This series included nine patients who had non-union of fracture of the neck of the femur and forty-seven patients who had various types of non-traumatic hip disability. The operations were performed for relief of pain and the restoration of motion. Almost complete relief of pain was obtained in 67 2 per cent. and marked improvement in 25 per cent. Restoration of satisfactory motion was obtained in 53.1 per cent. and improved in 29.7 per cent. of the cases. In unilateral cases, the results were somewhat better than those obtained for the group as a whole (relief of pain, 82.8 per cent; diminution of pain, 13.8 per cent.). In unilateral cases, satisfactory motion was restored in 65.5 per cent. and improvement in motion was obtained in an additional 20 per cent.

Pending the development of an ideal hip-joint prosthesis, there is a large group of patients for whom none of the present arthroplastic procedures is applicable or in whom one or another such procedure has already failed. For these there would appear to be but little choice other than the resection-angulation operation if painless motion is to be restored. Furthermore, on the basis of the present review of cases, this operation appears to be not only the "redemption operation" of choice, but merits careful consideration as a primary operation. Quite apart from its success in overcoming pain, it yields a very high percentage of good functional results, particularly in the patients with unilateral disability, for whom other types of prosthetic operations are now being recommended.

The resection-angulation operation has several distinct advantages. It has universal applicability and can be employed by every adequately trained surgeon in any well equipped hospital. Apart from the general condition of the patient, there are no contraindications to its use. Any patient in whom there are a pelvic wall and a femoral shaft can be rehabilitated. It should be emphasized, however, that the resection-angulation operation is not an arthroplastic procedure. Although it does aim to restore painless stability and mobility, its most important contribution seems to be the release of the pelvis. Meticulous attention must, however, be given to (1) careful preoperative determination of the postosteotomy angle and (2) unremitting supervision of the period of postoperative reeducation. These, rather than the elegance of surgical technique, are the essential elements in determining the success or failure of the procedure.

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BONE AND CARTILAGE FORMATION BY PERIOSTEUM

Assay of Experimental Autogenous Grafts *

BY JONATHAN COHEN, M.D., BOSTON, MASSACHUSETTS, AND PIERRE LACROIX, M.D.,
LOUVAIN, BELGIUM

From the Department of Orthopaedic Surgery and the Division of Laboratories and Research, The Children's Medical Center, Boston, and the Institut d'Anatomie, Université de Louvain, Louvain

The value of a bone-grafting procedure depends in part on the mechanical support it provides, in part on the character and amount of repair tissue elaborated by the recipient tissue elements in relation to the graft, and in part on the production of intercellular material by the graft—that is, its osteogenetic potency. This last aspect of the behavior of transplanted bone has repeatedly been subjected to experimental investigation in animals[4], as well as in tissue culture [1]. Much of this experimentation had as its objective the comparison of the osteogenetic potencies of different tissue elements as graft donors or recipients, and there emerged from this work the certainty that a variety of factors influence the type and amount of intercellular material produced.

These factors, on which the realization of the osteogenetic potency of any particular type of graft depends, have not been well defined. For example, one factor which has attracted much attention has been the source of the donor material, whether autogenous, homogenous, or heterogenous. It is still not certain how large a part this factor plays in the efficiency of bone-grafting, as witness the current use not only of autogenous and homogenous bone, but also of heterogenous bone in clinical practice [2]. Similarly, such other factors as the age of the experimental subjects, the character and size of the graft, the circulation of the recipient bed, and innumerable technical procedural details have been advanced as regulatory influences on the production of intercellular materials by grafts. No one set of conditions has received general acceptance as being optimal for elaboration of bone by different types of grafts; yet, if standardized assay procedures are to be developed, it is imperative that, for base-line reference, the optimal conditions be stated.

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The experiments to be described were performed as an approach to this problem. The study of a single variable, the recipient bed, was undertaken and the remaining known variables were standardized as much as possible. Thus, the periosteum was selected as the most homogeneous graft material with proved, easily demonstrable osteogenetic potency. Only autogenous fresh tissues were used, without being processed. Three sites of implantation were chosen for comparison because of their relatively homogeneous character and ease of duplication: the surface of the tibia denuded of periosteum, the anterior chamber of the eye, and the surface of the kidney under the capsule. The variation in efficiency of the three recipient sites in demonstrating osteogenetic potency constitutes the main subject of this report. The unexpected production, by these grafts, of cartilage which showed some of the characteristic sequences of endochondral ossification will also be described.

MATERIAL AND METHODS

The animals used for the most part were male rabbits of Flemish Giant strain which weighed 500 to 600 grams and were five weeks old. Under ether anaesthesia and aseptic precautions, the periosteum on the medial aspect of the middle third of the tibia was exposed and a strip 2 by 0.5 centimeter was outlined with a sharp scalpel. This strip was divided into three equal portions *in situ*. The first portion was removed and was inserted under the capsule of the right kidney by the method of Lacroix. The second portion was removed and was sutured with fine silk in the donor bed of the first segment. The third periosteal segment was then removed and was inserted into the anterior chamber of the eye. A stab incision was made into the anterior chamber with a pointed scalpel, and the periosteal graft was inserted and unfolded with a thin thumb forceps.

The grafts were protected from drying by contact, as much as feasible, with tissue fluids, and the interval between removal and insertion was kept to a minimum. The animals were housed in rather large cages and were observed to be moving about freely without disability after the first postoperative day. Their weight gain was satisfactory on a routine laboratory diet of pellets or hay and oats.

After appropriate intervals, the animals were sacrificed and histological preparations, some of them serial sections and others multiple sections, were made of the grafts. Fixation was in either Bouin's fluid or Zenker's solution. Decalcification was in 5 per cent. nitric acid, and embedding was in either paraffin or celloidin. Masson's trichrome stain or hematoxylin and eosin stain was used.

RESULTS

In preliminary studies, a few animals were sacrificed at intervals varying from four days to six weeks after operation. From these it was determined that in the weanling animals the time of sacrifice which was satisfactory for adequate demonstration of the production of intercellular matrix by the graft was in the neighborhood of ten to fourteen days. A small amount of bone was produced by the grafts even during the shortest experiments, which lasted only four days. Shorter postoperative intervals were not investigated. In the animals sacrificed two to six weeks after operation, the grafts did not elaborate significantly greater amounts of bone than in those sacrificed earlier, but there occurred

ASSAY OF BONE AND CARTILAGE PRODUCED AT DIFFERENT RECIPIENT SITES BY AUTOLOGOUS PERIOSTEAL GRAFTS

GRAFT SITE	No.	No. WITH BONY CALLUS	MAX. DIMENSION BONY CALLUS	SIZE OF CALLUS IN EACH GRAFT	No. WITH CARTILAGE	MAX. DIMENSION CARTILAGE
INTRAOCULAR	8	6	0.5 x 0.3 mm.	++ (2 CASES)	0	
				+ (4 CASES)		
SUBCAPSULAR	8	8	2.1 x 1.1 mm.	++++ (1 CASE)	2	0.96 x 2.2 mm.
				+++ (4 CASES)		
				++ (3 CASES)		
IN SITU	8	8	3.8 x 2.2 mm.	++++ (4 CASES)	8	2.8 x 1.6 mm.
				+++ (3 CASES)		
				++ (1 CASE)		

CHART I

the characteristic remodeling processes described for subcapsular periosteal grafts in rabbits[3] and for the periosteal grafts implanted into the anterior chamber of the eye in rats[4]. The principal results to be described are those found in eight animals which were sacrificed ten days postoperatively and which constitute the assay group. Later stages in the reactions of the grafts compared with those in the assay group will not be described in detail.

The amounts of bone and cartilage produced in these animals are listed in Chart I. The estimates of the relative quantities of bone or cartilage deposited by a graft were made in the following way. All the sections made from a block of tissue comprising the graft and its recipient bed were examined and measured with an ocular micrometer. While single sections showed great variation in these measurements, the composite uniformly was closely correlated with the measurements of the sections which contained most bone or cartilage. Therefore, when bone or cartilage was elaborated along the entire expanse of the graft as seen in cross section and when the thickness of the cartilage or bone was one millimeter or more, the response was called maximum, or ++++. When only a small nodule was deposited, the thickness of which was 0.25 millimeter or less, the response was called minimal, or +. Intermediate quantitative estimates were designated ++ and +++.

The grafts in the three different implantation sites differed significantly in their morphology, as well as in the amounts and types of intercellular substance deposited.

A. *Intra-Ocular Grafts*

In the grafts implanted into the anterior chamber of the eye (Fig. 1) the bone produced consisted of small nodules and in none of the sections did the entire expanse of periosteum lay down an uninterrupted layer of bone. The bone always had a very immature pattern—that is, its texture was loosely fibrous, the numbers of osteoblasts and osteocytes

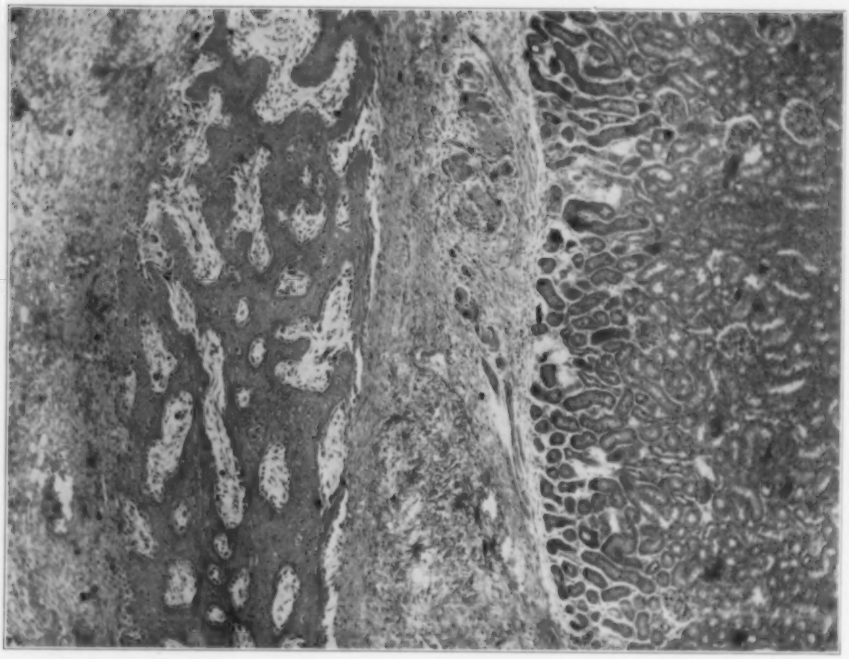

Fig. 2

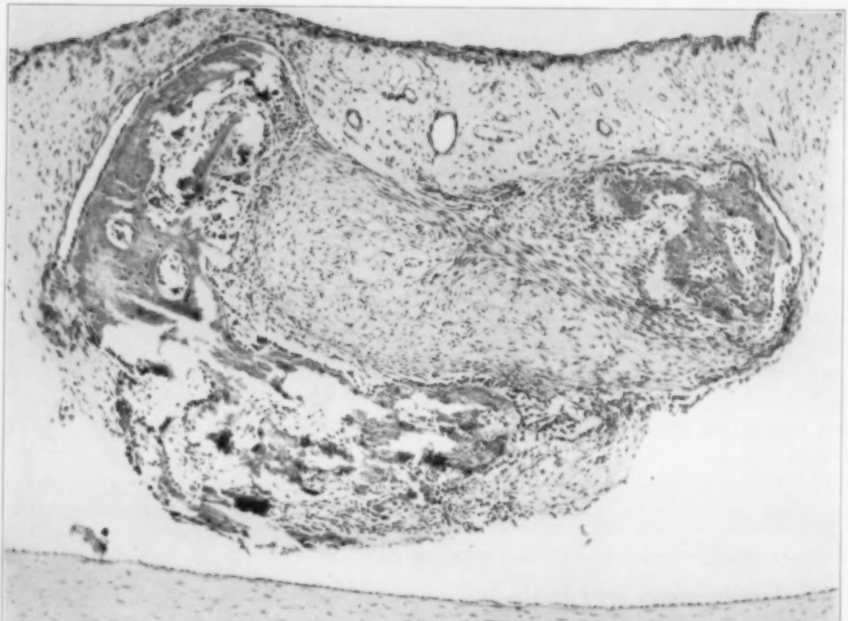

Fig. 1

Fig. 1: Photomicrograph of section (× 80) from an intra-ocular graft, which showed the greatest amount of bone formation. The cornea is at the left. Note the nodularity of the new bone. The reaction in the iris is minimal.

Fig. 2: Photomicrograph of a section (× 80) from a subcapsular graft. The periosteum intervenes between the kidney parenchyma and the graft, which is seen above the degenerating muscle fibers (center, right). Note the greater discontinuity and resorption of bone adjacent to the capsule compared with the subperiosteal layer.

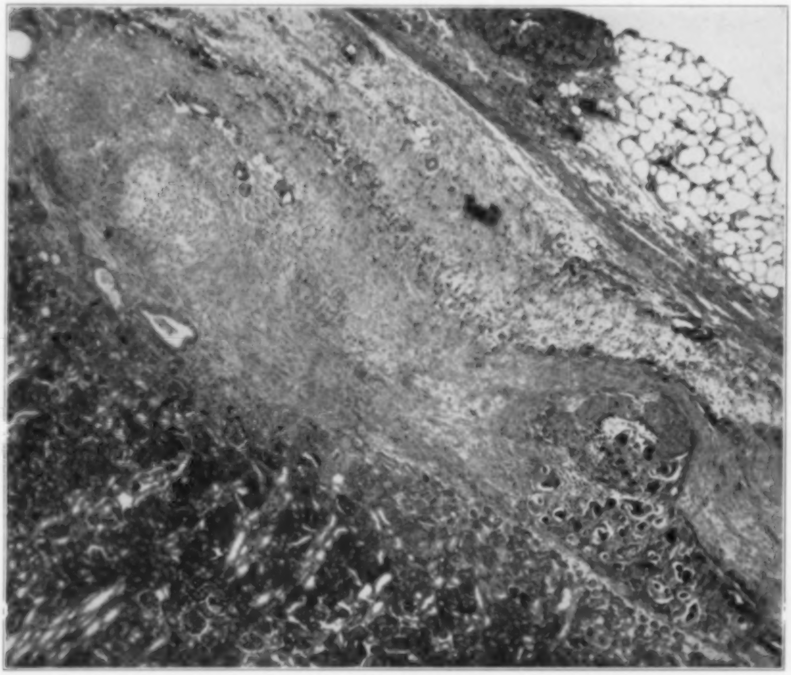

Fig. 3

Photomicrograph (× 60) showing cartilage and bony nodules in subcapsular graft. The cartilage nodule (left) is small and rounded, while the bony nodule (right) is irregular. Under it are numerous muscle fibers which show giant-cell formation and degenerative changes.

were large in comparison with the amount of matrix present, and trabeculation was rudimentary. The staining characteristics of the bone were heterogeneous, some portions staining variegated purple with hematoxylin-eosin, while neighboring areas were light pink, similar to osteoid. Often two discrete nodules appeared in a single section of a graft and, despite the attempts at operation to keep the periosteal surface smooth and flat, on section it was always found curled and folded and attached to the iris, but not to the cornea. The degree of cell proliferation in the cambium layer of the periosteum was not striking, and fibrosis of this layer, as well as of the outer fibrous layers of periosteum, was minimal. At the point of attachment of the iris to the graft, fibrosis was more active, although still not exuberant. Inflammatory reaction in the iris was minimal, and in no case was there frank infection.

B. *Grafts under the Kidney Capsule*

The grafts placed under the kidney capsule were characterized by a uniformly greater production of bone than the grafts placed into the anterior chamber of the eye. This bone was less immature than that described above and resembled callus. The pattern of the trabeculation, in general, was disposed parallel to the recipient bed. Often the entire graft, seen in cross section, was underlaid by a plaque of bone, but occasionally only a portion

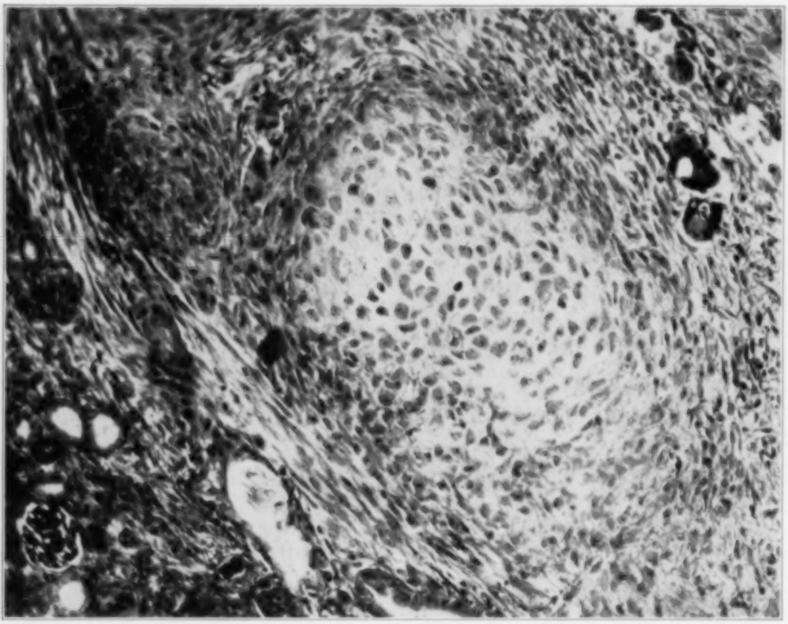

FIG. 4

Photomicrograph (× 120) of a nodule of cartilage showing at the left lower border the kidney parenchyma and at the right upper border the periosteal layer with a few degenerating muscle cells. The arrangement of cartilage cells shows that they are derived wholly from the inner layer of periosteum.

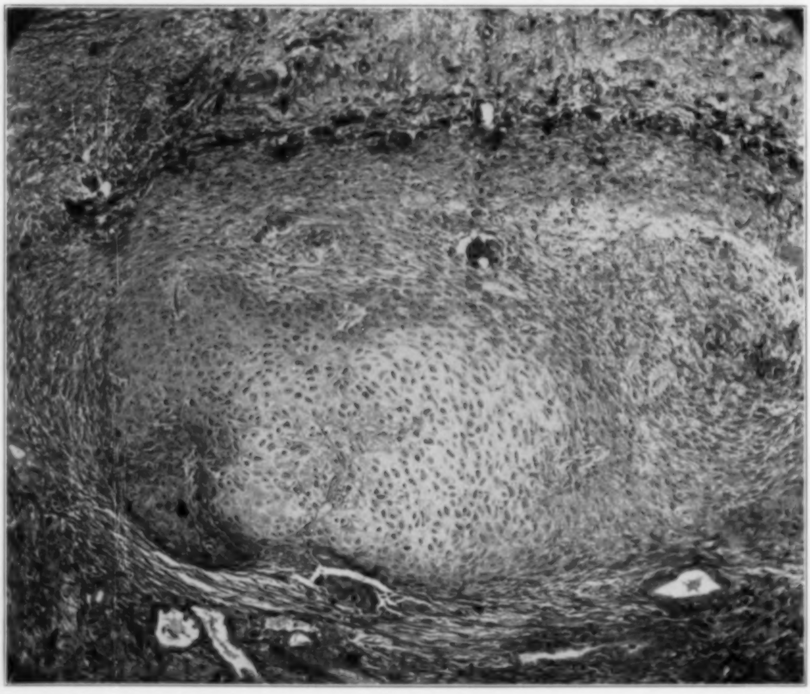

FIG. 5

Another nodule of cartilage (× 85). This nodule is furrowed; one vessel penetrates the mature cells at the base. Active continued formation of cartilage cells is seen at the periphery.

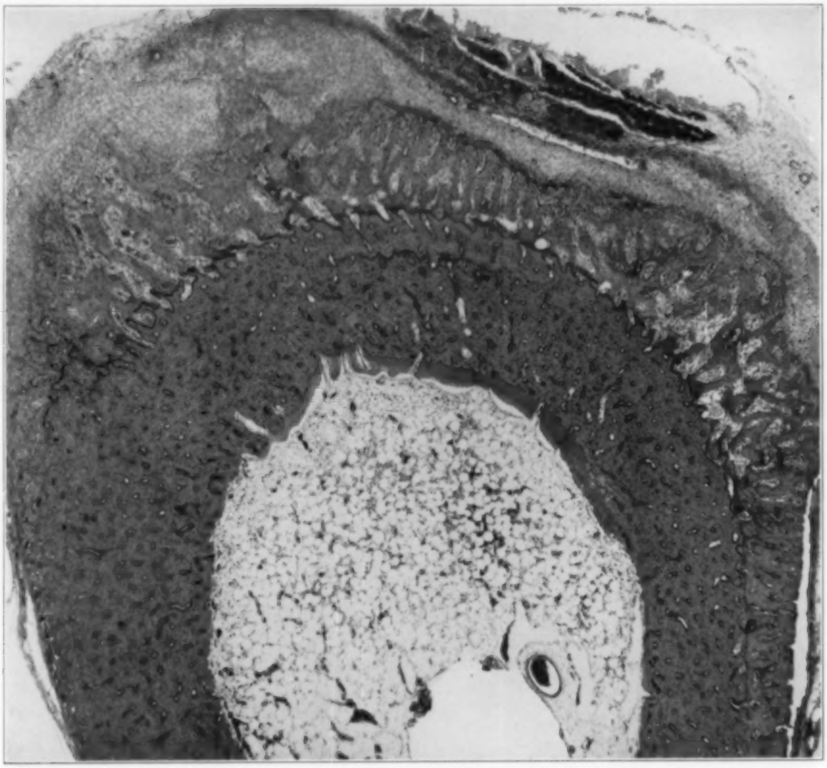

FIG. 6

Photomicrograph (× 27.5) of an *in situ* graft extending across the top of the section, producing cartilage at its border (left) and bone similar to callus elsewhere.

of the graft appeared thus, while the remainder, still viable, showed incorporation in the repair sequence of the capsule by fibrosis. The bone produced in four of these grafts had a uniform thickness in the central portion with a tendency to taper at the edges, while the bone of the other four grafts showed nodularity. There seemed to be little difference in the type and amount of bone produced, whether the periosteal graft was inserted facing the kidney parenchyma or facing the capsule; this confirms previous reports [3]. Nodularity of the bone produced was especially evident in the two specimens which also contained cartilage (Fig. 3) and in these the bone tended to be less mature than that in the specimen in which cartilage was not present.

In all grafts in this and the preceding group, the preponderant and probably sole source of the cells concerned with the elaboration of bone or cartilage undoubtedly was the graft. The kidney capsule and parenchyma always showed a moderate degree of repair by fibrosis with relatively few inflammatory cells. The two layers of the periosteum also exhibited a proliferative reaction consisting in a slight increase in the number of fibrocytes in the outer fibrous layer and profuse multiplication of osteoblasts in the inner cambial layer. The osteoblastic component often was four to six cells thick and overlaid the bone plaque, the superficial layer of which was usually smooth and thin, with a few hiatuses in which perforating vessels were found. In contrast, the surface of the bone plaque furthest from the periosteum usually was covered by osteoblasts in a layer only one cell in thickness, and hiatuses in this surface were more frequent. Remodeling sequences in the trabecular structure were quite active, and simultaneous resorption and deposition of bone in different areas occurred just as in fracture callus.

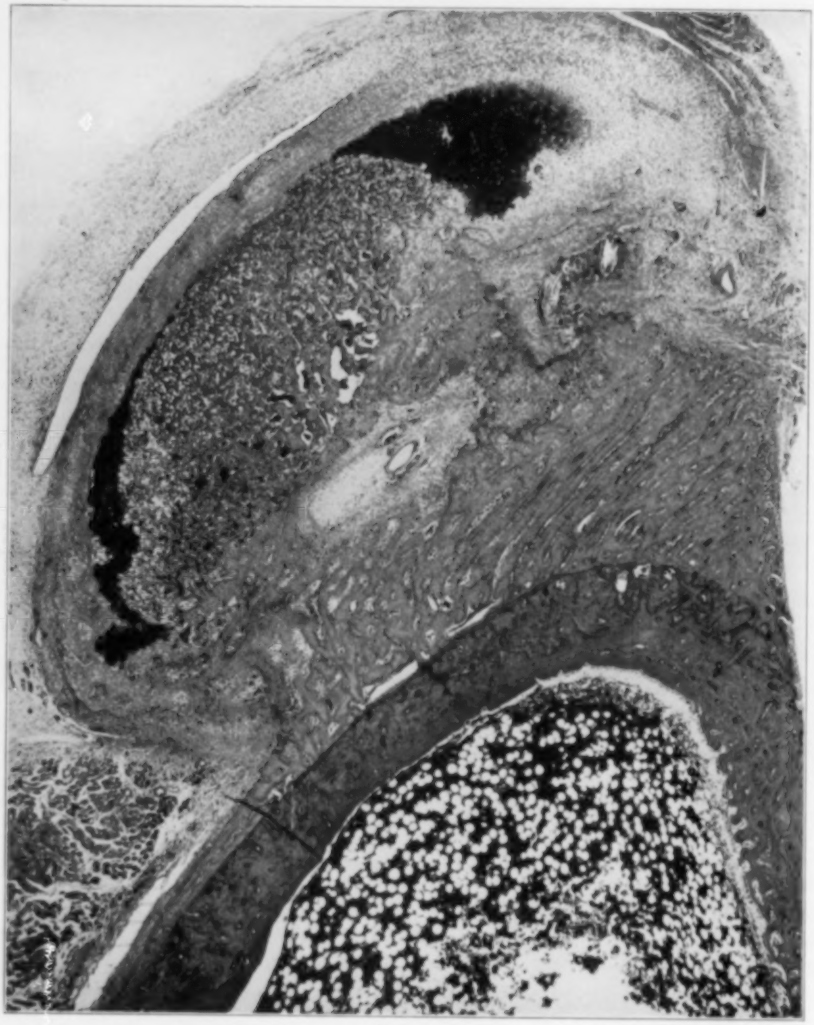

FIG. 7

Photomicrograph (× 27.5) of an *in situ* graft illustrating maximal cartilage production. The cartilage remains on either border of the graft and shows continuing elaboration. That in the center is undergoing endochondral ossification. Note the large amount of new bone subjacent to the cartilage compared with the small amounts of subperiosteal bone produced by the intact periosteum. The greatest portion of new bone in the section is derived from the graft. No endosteal reaction is evident.

In the subcapsular grafts of the assay group, two specimens (Figs. 4 and 5) demonstrated cartilage formation. The cartilage occurred as several small nodules, the largest of which, for each graft respectively, measured 0.96 by 2.24 millimeters and 0.51 by 1.2 millimeters in their maximal cross sections. In the animals not in the assay group, cartilage was also observed in the weanling rabbits after an interval of less than one week after operation. A few adult rabbits were used for the testing of subcapsular grafts in weanling as compared with adult animals. These animals are excluded from the assay group. They demonstrated elaboration of bone, but to a lesser degree than the weanlings; maximal thickness of bone was reached at about thirty days. Cartilage did not occur in

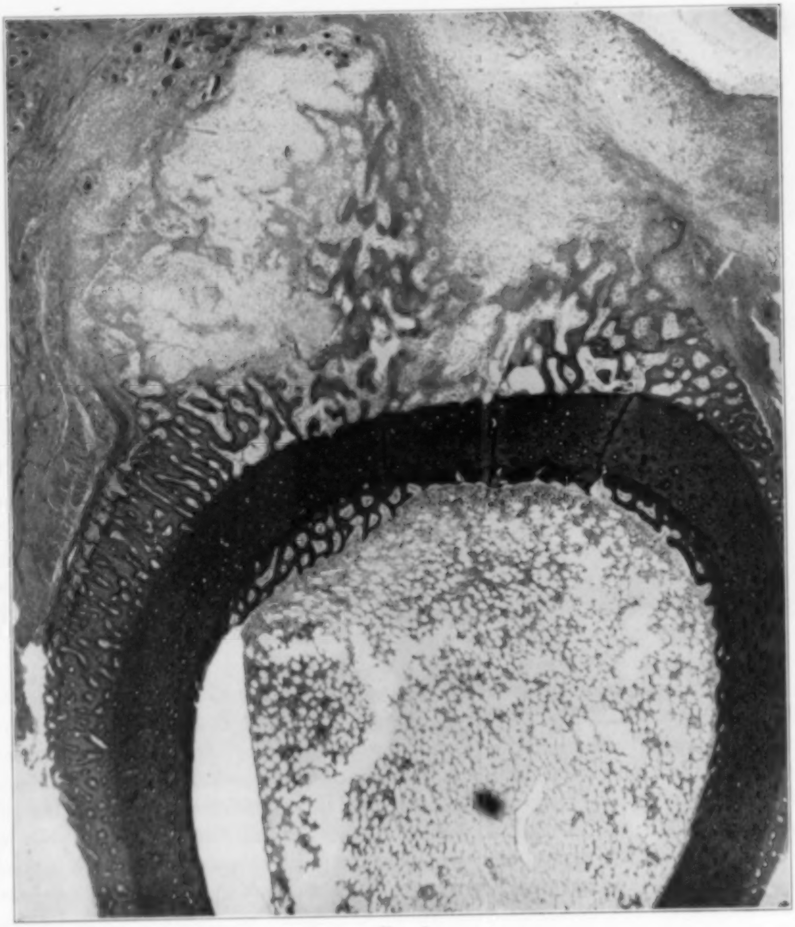

FIG. 8

Photomicrograph (× 30) of an *in situ* graft showing a large cartilage nodule. A slight endosteal reaction is evident. The amount of bone deposited by the graft far exceeds that produced by the intact periosteum. The irregular endochondral ossification of the cartilage is evident.

these grafts. Cartilage nodules occurred sporadically in the weanlings sacrificed after ten days, but the numbers of animals used for the longer-term experiments were not large enough to determine whether or not cartilage formation continued. The cartilage nodules were usually rounded or oval in cross sections, but occasionally a nodule was lobular or furrowed (Fig. 5). The cartilage cells corresponded in morphology and arrangement to those found in ordinary immature hyaline cartilage. The cellularity of the periphery of the nodules was much greater than that of the center, while the amount of matrix increased from the periphery to the central areas, indicating the usual interstitial growth of cartilage by matrix formation by the enclosed chondrocytes.

Patterns simulating certain elements of endochondral sequences were observed in one of the cartilage nodules. A transition was seen from the morphology of hyaline cartilage, with stellate cells containing oval nuclei encapsulated in small lacunae and irregularly distributed in rather abundant matrix, to the pattern characteristic of the "hypertrophic" cell zone of epiphyseal cartilage, containing cells encapsulated in very large lacunae with

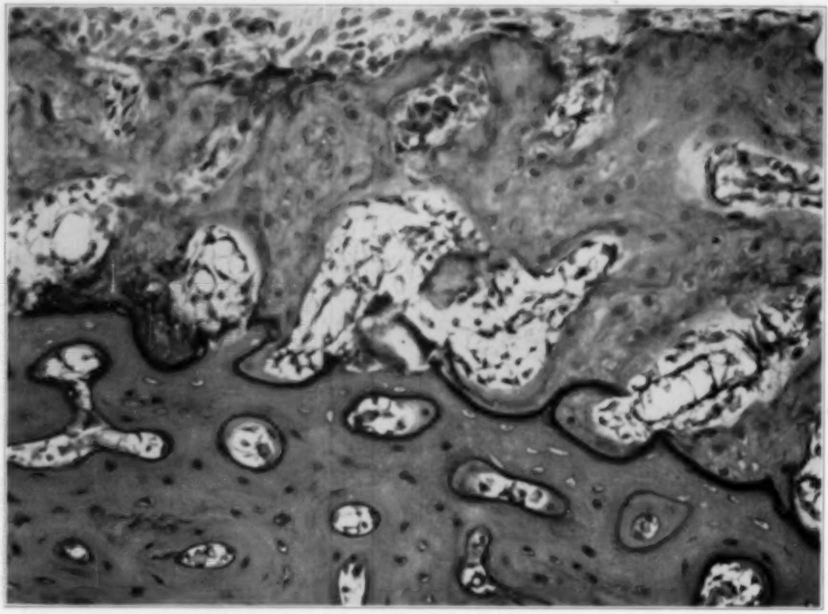

FIG. 9

Photomicrograph (× 250) of a section from the donor bed to illustrate perpendicular trabeculae of new bone deposited on the remains of circumferential lamellae. Numerous osteocytes in the superficial layer of the original cortex are necrotic.

scant matrix intervening. The orderly transformations of cartilage cell arrangements, as seen in epiphyseal cartilage (the irregular pattern of the "indifferent" cell zone, the columnar groupings of the "proliferative" cell zone, and the thin "hypertrophic" cell layer) were not seen. The "hypertrophic" cell stage seemed to occur without intermediate stages of regrouping and proliferation but resulted in a pattern of large cells, tending to columnar arrangement and separated by minimal amounts of matrix. It must be inferred that the intercellular matrix in these areas was resorbed by the cells.

Penetration of the "hypertrophic" cartilage cells by vessels was occasionally seen (Fig. 5) and a small amount of bone formation of very primitive type was present adjoining the vascular penetration. Other areas of the cartilage nodules showed metaplasia of cartilage to immature fiber bone, without trabeculation, but nowhere did this process extend beyond a very thin lamina.

C. *Grafts in Situ*

The sections of tibia containing *in situ* grafts showed profuse production of bone by the grafts and showed cartilage formation as well. One usually could not distinguish exactly between the bone produced by the graft and that produced in the tissue proliferating from the undetached periosteum peripheral to the donor bed or from the donor bed itself. It could be seen that all three of these areas contributed to a callus-like pattern of bone the trabeculae of which were continuous from one area of a cross section to the remaining portion. Only indefinite demarcations, indicated by persistence of cement lines, or orientation of trabeculae or fibers, existed as evidence of the source of each portion of reactive tissue. Therefore, only approximate measurements of the bone formed by the grafts were possible; these indicated that it far exceeded in thickness that of the intra-ocular and subcapsular specimens.

The tissues produced by the graft which were most interesting consisted of the cartilage nodules and bone. The bone differed little in configuration from callus (Fig. 6) and its confluence with the bone from the undetached periosteum and its relation to the donor bed have been described above. The cartilage, while frequently seen in nodules incorporated in the bone trabeculae, was most abundant directly under the grafted periosteum, where it often underlaid the graft throughout its extent (Fig. 7). The area where the periphery of the graft abutted the undetached periosteum frequently was the site of a cartilage nodule, and the origin of this nodule from the graft was evident from the orientation of the new-bone trabeculae (Fig. 8). Cartilage was not produced by the undetached periosteum in these experiments. The cartilage nodules varied greatly in size, but in general were characterized by an increased maturity compared with those nodules produced by subcapsular grafts, and the larger nodules seemed most mature—that is, they contained predominantly "hypertrophied" cells, and their matrix stained deeply. Occasionally, large portions of the original cartilage nodule had been invaded by the underlying fibrous tissue, with resultant disappearance of the chondrocytes, with traces of cartilage matrix remaining on which small amounts of bone were deposited. The resemblance to endochondral sequences of ossification was evident and the process was more extensive than in the subcapsular graft described above, but it also lacked order and the sequences of the "proliferative" cell zone. Nodules in different stages of maturity could be found in the same section at times, indicating continuing formation of these structures.

The pattern of proliferative reaction immediately adjacent to the recipient bed varied greatly, not only in different specimens, but in different areas of the same specimen. In some sections, the undetached periosteum over the entire circumference of the tibia showed active bone production, usually most profuse in areas immediately adjoining the donor site. In these regions, the trabeculae assumed an orientation roughly perpendicular to the surface of the tibia (Fig. 6), and the largest trabeculae of new bone occurred at the free edge of the undetached periosteum, with progressive diminution in size in areas away from the donor bed. In these specimens with intense periosteal reaction there often was significant endosteal proliferation of bone, but this was usually confined to the area directly underlying the donor bed and did not extend circumferentially. In other specimens, the periosteal proliferation of bone was less intense, with regard to both area and degree. In some, it extended through about half the circumference of the tibia; in these, no endosteal reaction occurred.

The donor bed, which also represented a recipient area in these specimens, showed one of the two following patterns, depending on the amount of new bone found. In the first, in which osteogenesis was extensive, the original superficial surface was irregularly eroded, so that discontinuous segments of the original subperiosteal circumferential lamellae remained (Fig. 9). Often, one or two of the most superficial layers of osteocytes had disappeared, leaving empty lacunae. The lacunae of the adjacent bone contained stainable cells and did not seem to be enlarged. Portions of the original subperiosteal bone served as a framework on which new bone was deposited, and the deposition took the form of perpendicular trabeculae when the amount of bone deposited was large. A heavy cement line could usually be seen between the old and the new bone. While erosion sometimes occurred in areas in which the lacunae were empty, it could also be seen in areas where there was no evidence of necrosis.

The second pattern, which occurred when the donor bed had only a small amount of new bone deposited on its surface, was seen less frequently than the first, and was always associated with slight displacement of the graft, either laterally or superficially. In either case, the bone produced by the graft was not directly continuous with that of the donor bed. The new bone laid down on the donor bed consisted of a circumferential lamella of variable thickness, without evidence of erosion. Instances were seen in which this lamella overlaid normal cellular bone, as well as bone in which the lacunae were empty.

Possible origins of the tissue which covered the donor bed included the soft tissues and periosteum peripheral to the area of excision, the donor bed itself, and the graft. In those sections in which the graft evidently had been raised a small distance from the bed, the area intervening between the bone and the cartilage produced by the graft and the donor bed consisted of a rather cellular fibrous tissue, the fibers and cells of which showed orientation tangential to the donor bed as well as to the graft. At its periphery this fibrous tissue merged with the fibrous tissues of the undetached periosteum and with the fibrous tissue of the periphery of the graft. It seems probable that this tissue did not arise from the donor bed, and that the graft did not produce fibrous tissue during the early postoperative period, judging by the orientation of the tissues. This fibrous tissue may have arisen from the undetached periosteum and soft tissues, or from the periphery of the graft, or from both. The fibrous tissue in question was closely apposed both to the circumferential lamella of new bone on the donor bed, and to the undersurface of the bone and cartilage produced by the graft. Active deposition of bone on the donor bed occurred through the agency of a row of osteoblasts which were derived either from the fibrous tissue or from cells in the underlying bone. In like manner, the undersurface of the graft, when distinct from the donor bed which showed predominantly resorptive processes, although some deposition of bone was also noted, merged with the fibrous tissue without definite demarcation. When the new bone in the graft and that in the donor bed were confluent, the direction of trabeculae was predominantly perpendicular to the donor bed, and never tangential Judging by this orientation and by the presence of empty lacunae in the donor bed, it seems probable that all or nearly all of the new bone was produced by the grafted periosteum in these instances.

DISCUSSION

From these experiments, it is evident that the recipient site has an important influence on the amount and character of the tissue elaborated by periosteal grafts. When one attempts to characterize the three areas used as recipient beds, in order to differentiate the individual stimuli at work in them, some inferences can be drawn from the morphological evidence, but adequate methods for measuring these stimuli are not at present available.

The first stimulus to bone formation to be discussed is the circulation of the three areas. The number and size of the blood vessels in the tissue sections and the amount of bleeding encountered during the operative procedure are the only available measures of local circulatory supply. No proportional relationship was found to occur between the amounts of bone or cartilage produced and the vascular supply as gauged by the criteria stated, since the vascularity of the kidney capsule certainly exceeds that of the tibial surface, yet the productivity of the kidney capsule was uniformly less. Additional evidence that the circulation of the host is not the single overriding regulator may be drawn from the histological studies. Thus, in nearly all the *in situ* graft specimens, the production of bone by the graft exceeded that of the undetached periosteum, which, although elevated somewhat by the operative procedure, retained sufficient connections to assure a better immediate blood supply than occurred in the free graft. Furthermore, the production of similar amounts and types of bone by the subcapsular grafts, regardless of whether these were inserted facing the kidney parenchyma or facing the capsule, may serve to confirm the limitations of a hypothesis of vascular regulators.

None of the grafts, whatever the site of implantation, showed obvious necrosis, whereas at the surface of the tibial donor site, in a few specimens, a thin layer of bone became acellular. Possible explanations of this observation may be the injury of the bone surface during operation, particularly by drying, or a greater sensitivity to circulatory interruption in bone compared to periosteum, but it seems more probable that the loss of osteocytes is more easily demonstrable than similar losses of fibrocytes and osteoblasts in the periosteal grafts. Such losses of cells in the graft would be impossible to demonstrate histologically.

Any consideration of the adequacy of nutrition of tissues must include attention to the intercellular fluid as well as to the vessels. The intricacy of arrangement of capillaries and arterioles in various tissues has been demonstrated, but no such studies are available on the vascularity of repair tissue. Ultimately, however, the intercellular fluid is the final pathway for the nutrition of cells, and is responsible for maintaining the viability of the grafts. The scarcity of information on the physiology of cellular nutrition at this level cannot be overemphasized. Thus, any explanation of the behavior of graft tissues based on circulatory or nutritional factors must be recognized as entirely speculative.

The second stimulus to bone production to be considered is the mechanical one. In the group of experiments described, any difference in mechanical arrangements among the three recipient sites is theoretical, and certainly not measurable. It is possible that the motion of muscles adjacent to the implanted *in situ* grafts could have elicited the large amounts of bone and cartilage, while the absence of such stimulation at the other sites resulted in a lesser reaction. This possibility becomes less likely when we consider the unevenness of histological distribution of the bone produced. Since the largest amounts underlaid the peripheral areas of the graft in most cases, the overriding influence of a mechanical factor would seem unlikely, inasmuch as whatever motion or pressure may have been transmitted by the action of muscles probably was uniform in respect to the surfaces of the grafts. Moreover, the presence of a thick, fibrous non-osteogenic layer between the muscle and the osteogenetic portion of the grafts renders mechanical explanations less convincing.

The third stimulus which must be considered is that of local chemical factors. The enzyme or enzyme system termed "alkaline phosphatase" constitutes one factor certainly active in the elaboration of bone. That it exists in large amounts in the kidney is of interest, but its pertinence in the quantitative regulation of bone production is doubtful. The specific activity of alkaline phosphatase in bone is far less than that which occurs in the kidney parenchyma, but in this regard attention must be drawn to the expression of specific activity in terms of tissue weights, which may be an inappropriate standard of reference. Undoubtedly other undefined local substances play a part in stimulating bone production and it is the isolation and study of these substances which seem to offer most to the investigation of processes in bone repair.

The production of cartilage by *in situ* and subcapsular grafts has not been reported previously. While the presence of cartilage in callus, particularly in young animals, is a matter of common knowledge, certain histological features of the cartilage produced in these experiments are worthy of mention. In the subcapsular grafts the cartilage nodules were small and irregular and not continuous with adjoining bone. In the *in situ* grafts the nodules were larger and more rounded and tended to occur at the borders of the graft, while neighboring, undetached periosteum produced no cartilage. These facts emphasize the importance of the magnitude of local stimuli influencing the potentialities in various parts of the graft. The production of cartilage occurred only in those specimens in which large amounts of bone were produced. It must, therefore, be inferred that, when the stimulus to osteogenesis was maximal, there also occurred a stimulus to cartilage formation. In these specimens the bone produced tended to be immature. The proliferative reaction of a group of cells such as those of the periosteum may be so arranged as to form a gradient of response to stimuli which induce the production of characteristic types of intercellular material and regulate the amount and fine configuration of the material produced.

We may finally indicate the degree of applicability of these experiments to clinical problems and to the understanding of fundamental processes of bone repair. Undoubtedly the reactions of the *in situ* grafts are qualitatively and quantitatively those of the periosteum which occur during fracture healing without the added variable stimulus of mobility of fracture fragments. Because of the parallel to fracture healing, the description of *in situ* grafts has been furnished in detail to include the significant fact that the response in bone to traumatic elevation of periosteum may be so extensive as to include the subjacent endosteum and this entire circumference of periosteum.

In the introductory sentence of this paper, it was stated that the clinical value of bone-grafting procedures depends on other factors in addition to the osteogenetic potency of the transplanted tissues. It is probable that the local mechanical and reparative influences far outweigh in importance the amount of bone produced by any of the elements of the graft. However, since the periosteum seems to be the most reactive of the components of bone, its inclusion in some grafting procedures may be of practical value.

CONCLUSIONS

The authors have attempted to devise a standardized method of assay of the ability to produce bone by a tissue to be used for grafting. Autogenous periosteum of rabbits was studied by this method and the osteogenetic potency of the tissue was found to vary considerably, depending on the age of the animal and the character of the recipient bed used. *In situ* grafts on the tibia were most successful, subcapsular grafts on the kidney moderately so, and grafts into the anterior chamber of the eye showed the least amount of osteogenesis. The formation of cartilage by grafts of periosteum was frequently noted. A gradient of response by a tissue has been described which includes the amount and type of intercellular material elaborated in response to stimuli. These local stimuli are believed to be primarily chemical rather than mechanical or circulatory.

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AN EVALUATION OF THE PUTTI-PLATT RECONSTRUCTION PROCEDURE FOR RECURRENT DISLOCATION OF THE SHOULDER *

BY COLONEL ERNEST A. BRAV, *Medical Corps, United States Army*

From the Orthopaedic Service, Walter Reed Army Hospital, Washington, D. C.

Recurrent or habitual dislocation of the shoulder, a condition recognized and treated by ancient physicians, has been the subject of considerable investigation in recent years. The essential pathological changes were described by Broca and Hartman in 1890 and have been further elucidated by the recent studies of Bankart [1, 2], of Bost and Inman, and of DePalma, Callery, and Bennett. The treatment of the condition has run the gamut, from the anterior scarification procedure of Hippocrates to the most complicated forms of joint reconstruction. The large number of operative procedures which have been advocated for the treatment of recurrent dislocation of the shoulder bears witness to the uncertainty of the end results.

Attention was drawn by Osmond-Clarke in 1948 to an operative procedure used independently by Vittorio Putti and by Sir Harry Platt for the treatment of recurrent dislocation of the shoulder. This procedure has the advantages of relative technical simplicity and of usefulness in any case of recurrent dislocation, regardless of the etiology or of the existing pathological changes. Its disadvantage, as in the other recent relatively successful forms of operative treatment, is that, in accomplishing its purpose, it also results in some residual limitation of external rotation of the shoulder. This limitation, together with operative scarring of the anterior portion of the glenoid labrum and of the capsule, is the theoretical mechanism of the curative effect.

PRESENT SERIES

During the past five years, the author and his associates have treated sixty-nine patients with recurrent dislocation of the shoulder by the Putti-Platt operative procedure. In the first thirty-one patients, the exact technique, as described by Osmond-Clarke, was utilized.

An anterior incision was made, starting at the acromioclavicular joint, curving along the medial aspect of the coracoid process, and continuing downward in the line of the deltopectoral groove. By blunt dissection between the deltoid and the pectoralis major muscles, the anterior surface of the shoulder joint was visualized. For a better exposure, the proximal anterior fibers of the deltoid were divided horizontally from the clavicle for a distance of about five centimeters at a point 1.5 centimeters distal to the bone. The conjoined tendon of the short head of the biceps and the coracobrachialis muscles was severed just distal to the tip of the coracoid process.

With the arm placed in external rotation, the belly of the subscapularis muscle was incised vertically from its superior border to the three horizontal veins which mark its inferior edge. Before incision, three or four sutures of No. 1 chromic catgut had been placed in the medial side of the proposed line of incision and held by straight hemostatic forceps for the purpose of retraction and identification. The incision was made approximately two centimeters medial to the attachment of the mucles to the lesser tuberosity, where there is a distinct line of cleavage between muscle and anterior capsule. The capsule was then incised vertically in the line of the muscle incision, after sutures had also been placed medially along the incision line, as in the muscle. These sutures were held by curved hemostatic forceps for easy differentiation from those in the muscle.

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* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 25, 1954.

A very satisfactory exposure of the interior of the shoulder joint was obtained with the arm held in internal rotation and with medial and lateral retraction of the anterior muscle and capsular layers. The pathological changes in the glenoid labrum and the head of the humerus were noted, and a search was made for loose bodies, defects of the glenoid cavity, and any abnormal bursal openings. If the glenoid labrum was found to be detached, the anterior edge of the glenoid cavity was curetted. The anterior portion of the glenoid labrum itself was not removed unless it was completely separated from bone and capsule.

With the arm still held in internal rotation, the forearm resting across the abdomen, the lateral edge of the subscapularis muscle was sutured with three sutures of No. 1 chromic catgut to the portion of the glenoid labrum remaining at the anterior edge of the glenoid cavity. If the glenoid labrum had entirely disappeared, or if a completely separated labrum had been excised, the sutures were fixed to the deep surface of the reflected capsule along its normal attachment to the anterior glenoid margin. These sutures were sometimes difficult to place, but this procedure represented the only technical problem in the operation. There also appeared to be considerable doubt as to their eventual efficacy in the joint reconstruction.

The medial portion of the capsule was next drawn laterally and sutured to the soft tissue just lateral to the bicipital groove. Supplementary interrupted chromic-catgut sutures were used to secure the repair. In some cases the capsule would not stretch beyond the bicipital groove, and the sutures were then placed just medial to the groove or into the biceps tendon itself. The final layer of closure consisted in suturing the medial portion of the subscapularis muscle to the soft tissues lateral to the bicipital groove with reinforcement by a few additional interrupted sutures. This layer could be drawn laterally without difficulty to this shortened position in every case.

The conjoined tendon and the deltoid fibers were then re-attached to their insertions, and the edges of the deltopectoral groove were approximated by interrupted sutures of No. 0 chromic catgut. After skin closure, the opposing surfaces of the arm and the chest were protected by talcum and gauze; the patient's forearm was placed across his chest and maintained by a bias stockinette dressing. After a period of four weeks, graduated exercises were instituted.

It was noted in our earlier patients that the subsequent limitation of external rotation ranged between 10 and 30 degrees. It was our feeling that, if the primary layer of sutures uniting the lateral edge of the subscapularis muscle to the glenoid margin remained intact, there would be a much greater residual degree of limitation. We concluded that, with the resumption of shoulder motion, this deep layer of repair was not maintained and that the moderate degree of limitation was due to the more superficial overlapping of the capsule and the muscle layers. In view of this observation, we have treated our last thirty-eight patients by a simplification of the original Putti-Platt procedure without any apparent loss of effectiveness. The technique has been modified as follows:

1. *Skin incision:* The long curved anterior incision has been replaced by the classical oblique, anterior shoulder approach in the line of the deltopectoral groove. The cosmetic improvement has been considerable.

2. *Ligation of the cephalic vein:* In order to avoid embarrassing hemorrhage during the operative procedure, the cephalic vein is isolated and ligated at the upper and lower levels of the incision. If this vein is not ligated, it may be injured at the time of wound closure with the possibility of subsequent postoperative formation of a hematoma. There have been no static circulatory ill effects from ligation of the cephalic vein.

3. *Joint exposure:* With the simplified operative approach, it is unnecessary to incise the deltoid fibers or to separate the conjoined tendon from the coracoid process. Even in heavy-set individuals, excellent exposure of the anterior aspect of the shoulder joint can be obtained by simple retraction. The time required for the operation is shortened, and the

period of postoperative immobilization can be safely reduced.

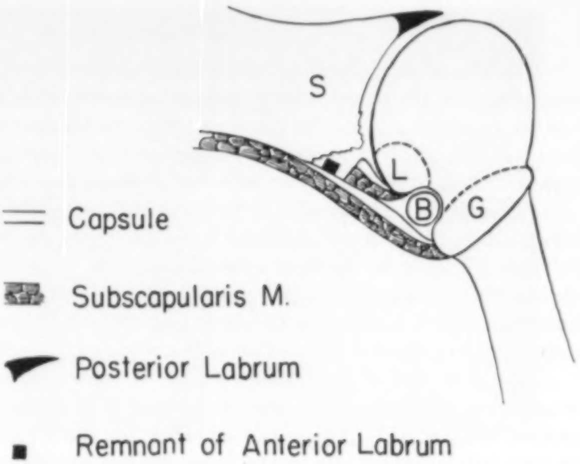

FIG. 1

Schematic drawing of horizontal section through a shoulder joint following the simplified Putti-Platt reconstruction procedure. *S*, scapula; *G*, greater tuberosity; *L*, lesser tuberosity; *B*, biceps tendon.

4. *Intra-articular surgery:* We believe that extensive exploration of the joint is not required for successful operative repair and that the procedure may actually be carried out without wide exposure of the anterior glenoid margin. However, we feel that inspection of the interior of the joint is desirable, in order to observe the existing pathological changes, and also to determine if there is present a completely severed glenoid labrum or a free osteocartilaginous body, either of which requires excision. Curettage of the glenoid margin has been eliminated in most cases, because we feel that it is of questionable value in encouraging re-attachment of the glenoid labrum or the stripped capsule. Such treatment, in fact, might produce subsequent degenerative changes by causing the separation of small bony fragments into the joint.

5. *Repair of anterior structures:* Since the attachment of the short lateral stump of the subscapularis muscle probably separates from the anterior glenoid margin when shoulder motion is resumed, this technically difficult part of the operation can be omitted. In the original procedure, the end result is apparently an adherence of this short stump of muscle to the deep surface of the capsule which is drawn over it. In the simplified procedure, the same effect is accomplished simply by thrusting the lateral stump of the muscle beneath the capsule, drawing the capsule over it in the prescribed manner, and suturing the capsule to the soft tissues of the outer side of the bicipital groove, while the arm is held in internal rotation. The resultant adherence of the distal stump of the muscle to the capsule, with the associated formation of scar tissue, apparently produces the same resistance to anterior displacement of the humeral head as was accomplished by the original procedure (Fig. 1). By overlapping the medial portion of the subscapularis muscle, the third layer of repair is performed as in the original manner.

6. *Wound closure:* The deltoid muscle and the conjoined tendon are not severed during the simplified procedure, and closure of the wound, which consists in the application of a few interrupted chromic-catgut sutures to the deltopectoral groove, is considerably simplified. Since the tissues fall together naturally upon removal of retraction, it is probably unnecessary to use any sutures between the joint repair and the skin.

7. *Postoperative management:* We have been able to reduce the period of postoperative immobilization to three weeks. At the end of this period, a sling is used for an additional week and during this time pendulum rotation of the shoulder is encouraged. At the end of four weeks, intensive physical therapy, consisting of heat and active shoulder exercise, is begun. The reduction of postoperative immobilization has considerably decreased the period of rehabilitation required. The necessity for postoperative manipulation of the shoulder to regain movement is minimized, thereby avoiding possible complications incident to such procedure.

STATISTICAL STUDY

We have observed forty of our patients for a sufficient period to analyze the functional results. One of the patients had bilateral operative procedures. In all of these cases, there has been a minimal period of two years since operation. It is our feeling that, if recurrence is to follow a corrective procedure under ordinary circumstances, exclusive of additional severe trauma, it will probably be noted within a two-year period following surgery.

Sex and type: Thirty-nine of the patients were males, and there was one female. Recurrent dislocation of the shoulder is usually noted in stocky, muscular individuals and in those engaging in vigorous athletic activities. It is not infrequent in epileptics, and there were two dislocations (one patient) of this type in our series. It must be emphasized, however, that it is exposure to injury and not sex and body type which predisposes the individual to recurrent dislocation of the shoulder.

Age: The ages of our patients varied between eighteen and forty-one years, the average being 23.8 years. Any type of dislocation of the shoulder is uncommon in children, and recurrences are infrequently seen before the age of eighteen. Apparently the stretching of periarticular structures or the joint changes associated with aging predispose to dislocation and recurrence. However, with advancing years, there is intra-articular and periarticular fibrosis which limits external rotation so that recurrent dislocation is practically non-existent after the age of forty. It is also apparent that individuals over forty years of age are less frequently exposed to the athletic and occupational traumata which produce dislocation. These factors seem to counterbalance the advancing degenerative changes which predispose to recurrence.

Side of dislocation: Seven of the forty patients gave a history of bilateral recurrent dislocation (but operation was performed on both shoulders in only one of these patients). One patient reported a familial tendency to the condition. The recurrent dislocation occurred on the right side in sixteen cases, and in three of these the patients were left-handed. The condition occurred on the left side in twenty-five cases, and in none of these was the patient left-handed. Excluding the bilateral cases, recurrence was twice as frequent on the left side as on the right, and both of the left-handed individuals in this group had right-sided dislocations. The more frequent incidence of recurrent dislocation on the subdominant side suggests that inferior muscular development and coordination may play a part in the etiology of the condition.

History of trauma: There was a definite history of injury to the shoulder as the cause of the original dislocation in thirty patients. In twenty-three dislocations the injury was due to a fall on the shoulder or on the outstretched hand. Many of these injuries originated in body-contact athletics. In seven dislocations, the original dislocating injury was a mild strain, such as in vigorous swimming or delivering a boxing blow without striking an opponent. In eleven dislocations (26.8 per cent.), there was no history of injury, and the dislocations from the very first occurred by some simple shoulder motion without any type of strain.

Treatment of original dislocation: Only seven patients stated that there was immobilization of the shoulder following the original dislocation. Thirty-four initial dislocations (82.9 per cent.) were either treated by a simple sling or were not treated at all. Concerning the duration of the original treatment, only eight dislocations were treated for a period longer than two weeks. In thirty-three dislocations (80.5 per cent.), there was either no immobilization or immobilization was discontinued at the end of two weeks.

ROENTGENOGRAPHIC FINDINGS

Roentgenograms of the shoulders of sixty-five patients were considered adequate for proper interpretation. Roentgenograms were made with the shoulder in moderate abduction and in about 60 degrees of internal rotation. Anteroposterior views were made in all

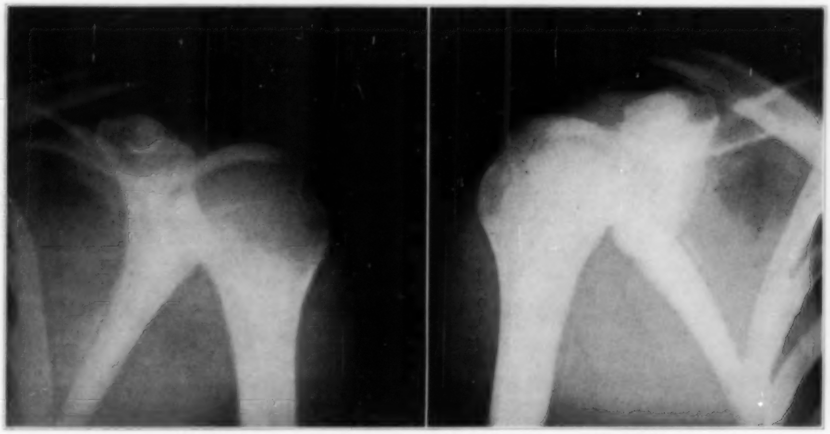

FIG. 2-A FIG. 2-B

Fig. 2-A: Anteroposterior roentgenogram of shoulder of patient who had a typical defect in the posterolateral portion of the humeral head, which was identified at the time of operation.

Fig. 2-B: Similar roentgenogram of the opposite shoulder of same patient, showing identical appearance. There was no history of injury or of any difficulty with this shoulder.

cases, and, in some, additional tangential axillary roentgenograms were made. The opposite shoulders were always examined for comparison with the side of dislocation. In forty-one shoulders, a defect in the posterolateral portion of the humeral head was noted; in twenty-six shoulders the defect was bordered by a sharply defined vertical line of sclerosis, and in fifteen there was some flattening of the humeral head but no definite notch or groove. Roentgenograms showed loose bodies in the joint in four cases and evidence of proliferation of the inferior glenoid margin in twelve. Cystic changes were noted in the head of the humerus in eight patients.

Seven patients had bilateral recurrent dislocations, and in these cases the roentgenograms revealed changes in the shoulders opposite the one under treatment. In two other patients, there were typical defects in the opposite shoulders, although the patients themselves gave no history of injury to these shoulders and had no complaints suggesting any local abnormality (Figs. 2-A and 2-B).

OPERATIVE FINDINGS

In sixty-nine shoulders, the joint structure was examined carefully at the time of operation, in order to observe the pathological changes and to determine if possible the cause of recurrence. In most patients the subscapularis muscle was well developed and of normal appearance. In a few it seemed somewhat atrophic, but no congenital anomalies of the muscle were noted. Loose bodies were present in the joint in six patients, although they had been detected in only four by roentgenogram, and there were definite flattening and inadequacy of the glenoid cavity in three. In four patients the opening frequently found between the joint cavity and the overlying subscapularis bursa was greatly enlarged, and this seemed to play a part in the instability of the joint.

A defect in the posterolateral portion of the humeral head was found in twenty-two patients. Adequate exposure for palpation of the defects was not obtained in all cases, although the shoulder was placed in marked external rotation; so that even though the defects had been clearly demonstrated on the roentgenograms in many instances, they were not always palpable.

The most constant pathological change noted in our patients was the thinning of the anterior and inferior portion of the glenoid labrum and the separation of this structure from its normal attachment to the bony rim of the glenoid fossa. In thirty-seven cases

TABLE I

TWO-YEAR RESULTS FOLLOWING THE PUTTI-PLATT SHOULDER RECONSTRUCTION

Results	Total (*No. of Shoulders*)	Original Method Used (*No. of Shoulders*)	Simplified Method Used (*No. of Shoulders*)
Procedure used	41	22	19
Recurrences	3 (7.3 *per cent.*)	1	2
Sensation of instability	17	9	8
Subjective stiffness	15	7	8
Limitation of athletic activity	20	9	11
Significant pain	5	2	3
Weakness	17	8	9
Patient's estimation of result			
Good	34	20	14
Fair	5	2	3
Poor	2	0	2
Patient would not recommend operation	3	1	2

(Type II), this defect of the glenoid labrum was moderate in extent, and the anterior capsule was separated with the labrum for distances of one-quarter to three-eighths of an inch from the scapular neck, leaving an area of irregular, roughened, and sometimes eburnated bone. Occasional osteophytic lipping was observed.

In twenty-two patients (Type III), the degeneration and separation of the glenoid labrum and the extent of capsule stripping were much more marked. In these cases there was often an area of separation of the capsule from the scapular neck extending an inch or more from the glenoid margin. In a few cases, there were large openings into the subscapularis bursa. Usually, in these cases, the glenoid labrum itself was either so degenerated as to be barely distinguishable or it was a thin band displaced into the joint like the bucket-handle type of torn meniscus of the knee.

There were ten patients (14.5 per cent.) in whom no separation of the anterior portion of the glenoid labrum or joint capsule could be detected (Type I). In a few of these patients, there was some thinning of the glenoid labrum but no displacement of this structure from its normal point of attachment.

OPERATIVE RESULTS

The two-year operative results in the group of forty patients who were adequately followed are presented in Table I. It will be noted that there was recurrence postoperatively in three patients (7.3 per cent.). In one of these patients, the recurrence was the result of a football accident. Recurrence in the other patients was unaccompanied by further injury. Some limitation of external rotation of the shoulder had been noticed by all three patients following surgery, but this limitation did not prevent recurrence.

Operative complications included one wound infection, which did not prevent a successful result. Three patients required subsequent manipulation under anaesthesia because of shoulder stiffness. In one patient there was a temporary, partial, musculocutaneous nerve paralysis resulting from the retraction required for exposure with the original operative technique. This complication should not be encountered with the minimal exposure required for the simplified procedure.

DISCUSSION

The pathological changes noted in patients with recurrent dislocation of the shoulder are well recognized, but the pathogenesis of the disorder remains controversial. It is agreed

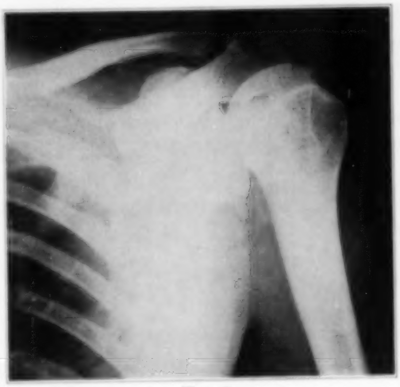

FIG. 3

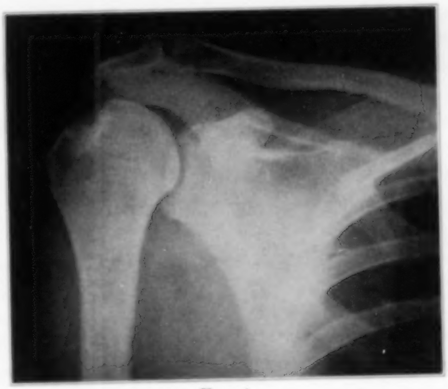

FIG. 4

Fig. 3: Anteroposterior roentgenogram of patient with recurrent dislocation of the shoulder, showing typical notched defect in the humeral head accompanied by a marginal vertical line of sclerosis.

Fig. 4: Anteroposterior roentgenogram of a shoulder one week after the original traumatic dislocation with associated compression fracture of the posterolateral portion of the humeral head. The striking similarity to Fig. 3 suggests that trauma is the probable cause of humeral-head defects in most patients with recurrent dislocation of the shoulder.

that the normal anatomy of the shoulder joint makes this structure mechanically unstable at best, and that any superimposed abnormality, whether congenital or traumatic in origin, which involves bony structure, capsule, cartilaginous labrum, or neuromuscular support, may be the inciting cause of recurrent dislocation. We have been impressed by the considerable number of patients who gave no history of an original severe injury, by the frequency of bilateral incidence, and by the occasional familial nature of the condition. This would seem to be convincing evidence that, at least in some cases, a congenital abnormality or a familial predisposition is the basic underlying factor.

We made an attempt to determine whether the associated humeral-head defects might be congenital in origin, as suggested by some of the French observers [10]. It has been demonstrated by certain investigators, notably Hill and Sachs, that these bone defects are usually produced at the time of the initial dislocation and are in the nature of compression fractures of the cancellous bone structure, resulting from sharp collision of the humeral head with the inferior glenoid margin. Figure 3 represents the typical roentgenographic appearance of the notched defect and the vertical line of sclerosis which are noted in many patients with recurrent dislocation of the shoulder. Figure 4 shows a fresh fracture of the head of the humerus which was sustained at the same time as the original anterior dislocation of the shoulder. The striking resemblance of the two roentgenograms suggests that the bone trauma sustained in the initial injury is the usual origin of the defect in the humeral head.

However, roentgenograms of two patients in the group revealed similar defects in the humeral head in the shoulder opposite the injured shoulder, although the patients had no history of injury and no symptoms suggesting dislocation. We have investigated the possibility of a congenital abnormality of the humeral head as the basis for the notched defect by examining roentgenograms of 100 shoulder joints in young individuals who gave no history of injury or symptoms of dislocation. The roentgenograms were made in the anteroposterior and tangential planes with the shoulder in 45 degrees of abduction and 60 degrees of internal rotation. In twenty-eight of these shoulders, there was abnormal flattening of the posterior portion of the head of the humerus, and in one there was proliferation of the inferior glenoid margin. In none of them was there a groove or a notched defect, and none presented a vertical line of sclerosis. We concluded that the flattening of the head represented a possible additional weakness of the structure of the shoulder joint

TABLE II

DEFECTS OF THE HUMERAL HEAD IN RECURRENT DISLOCATION OF THE SHOULDER

		Changes in the Labrum (*No. of Cases*)			Evidence of Defects in the Humeral Head	
	No. of Cases	Type I	Type II	Type III	No. of Cases	Per cent.
Entire series	69	10	37	22	46	66.6
History of trauma	53	8	28	17	40	75.5
No trauma	16	2	9	5	6	37.5

which might predispose to dislocation, but that the grooved defect of the head, at least in the majority of cases, was due either to the trauma of the original dislocation or to the effects of the subsequent recurrences.

As further evidence of the relationship between actual trauma and the defects in the posterior portion of the head of the humerus, we studied the incidence of these defects in the patients who gave no history of severe trauma in their original dislocations. Defects in the humeral head were found in forty-six patients in the series. In seventeen cases, defects were noted on the roentgenograms and were found at operation. In five patients, the defects were discovered during surgery. Roentgenograms of twenty-four patients revealed defects which were not disclosed by surgery. It is interesting to note that while the incidence of defects in the humeral head was twice as great in the traumatic as in the non-traumatic cases, the severity of the damage to the glenoid labrum was essentially the same in the two groups (Table II).

Defects in the humeral head were not always present in patients in whom no defect in the glenoid labrum could be established at operation. In our patients with Type I changes of the labrum, in which there was no significant abnormality in the anterior portion of the joint structures, the incidence of defects in the humeral head was 70 per cent. In patients with Type II and Type III changes of the labrum, in which there were definite degeneration and stripping of the capsule and labrum, the incidence of humeral-head defects was 66.1 per cent.

Inadequate treatment of the primary dislocation seems to be an important factor in the incidence of recurrence. Although it has been demonstrated that a certain percentage of patients who have had inadequate treatment of the original shoulder dislocation will not have recurrences, it has also been observed that the incidence of recurrence is considerably higher in patients who have not been adequately treated than in patients who have been immobilized properly for a minimal period of four weeks. It is our belief that all original dislocations should be so treated, regardless of the mechanism of the injury. However, it is probable that those original dislocations which occurred spontaneously will recur with or without treatment.

In spite of convincing arguments by the proponents of various theories on the pathogenesis of recurrent dislocation of the shoulder, a careful analysis of the possible etiological factors and the known pathological changes can lead only to the conclusions that there is no common cause of the condition; that there is no single abnormality which can be designated as the "typical defect"; that there is no special type of individual who is susceptible; and, unfortunately, that there is no operative procedure which will consistently, even when properly performed, prevent redislocation and also restore normal shoulder function.

The Putti-Platt operation, especially the simplified form, requires no unusual technical skill and no special surgical equipment. In our hands it has proved effective in the treatment of recurrent dislocation of the shoulder, regardless of the etiology or the pathological changes which exist. It does not produce a normal shoulder, but recurrence has been avoided in 92.7 per cent. of our patients, and, in spite of subjective complaints of residual stiffness, intermittent discomfort, and interference with athletic activities, only three patients have expressed dissatisfaction.

It is inadvisable to perform reconstructive procedures for recurrent dislocation of the shoulder in less than thirty days after any true recurrence because of the possible weakness and friability of muscle and joint capsule resulting from hemorrhage. This condition makes the shortening and suturing of these tissues a difficult procedure, and it may result in inadequate repair. It is also essential that the capsule and muscle repair be accomplished in individual layers, since these tissues will usually shorten to different degrees, and tautness of both structures is the basic principle of the corrective procedure. Since it is difficult to be certain in any case whether repair of the muscle or of the capsule will be the more important factor in prevention of recurrence, equal attention must be given to the proper treatment of both of these structures. This individual repair of the capsule and the muscle in layers is the feature which distinguishes the simplified procedure from the muscle transposition operation described by Magnuson and Stack.

While limitation of external rotation of the shoulder is one of the desired effects of the operation in preventing recurrence of dislocation, it is well to remember that the limitation is rarely more than 30 degrees and adequate functional recovery is the rule. Furthermore, all three of our patients who had postoperative recurrences gave histories of having limited shoulder rotation, which apparently did not prevent redislocation. We feel that the effectiveness of the Putti-Platt reconstruction is due not so much to the limitation of external rotation as to the resistance which is given to the anterior thrust of the humeral head by the operative scarring and by the shortened capsular and muscle structures.

SUMMARY

1. A study of the two-year functional end results of forty-one Putti-Platt reconstruction operations has shown that this procedure is effective in the treatment of recurrent dislocation of the shoulder, regardless of the etiology or the pathological changes. The procedure is available to any qualified surgeon and no special surgical equipment is required.
2. The simplified operation has been as successful as the original technique and has the advantages of decreasing the length of the incision, lessening the amount of tissue trauma, minimizing intra-articular operative damage, and shortening both the duration of the operation and the period of rehabilitation.
3. Shoulders in which original traumatic dislocation has occurred should be completely immobilized for a minimal period of four weeks, regardless of the mechanism of injury, in order to reduce the possibility of recurrence. Dislocations which are spontaneous will probably recur with or without immobilization.
4. Operative correction should be reserved for disabling recurrences in young individuals who are willing to accept the attendant postoperative limitation.
5. Because of the friability of the soft tissues secondary to the trauma of dislocation, operative repair should not be attempted in less than thirty days after any recurrence.
6. Since in all three of our operative failures, the patients had persistent limitation of external rotation, it is suggested that the effectiveness of the procedure is due principally to the resistance given to the anterior thrust of the humeral head by the operative scarring and by the shortened capsular and muscle structures.

NOTE: Since reporting these statistics, the author has learned the two-year operative results in five additional patients treated by the simplified Putti-Platt procedure. There has been no further incidence of postoperative recurrence.

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DISCUSSION

Dr. Carter R. Rowe, Boston, Massachusetts: The Putti-Platt operative technique for recurrent dislocation of the shoulder has had wide application and has proved to be a very satisfactory procedure.

Col. Brav's experience with the *standard* Putti-Platt procedure has been very good; the postoperative recurrence rate in the nineteen patients in whom the *simplified* Putti-Platt procedure was used was 10 per cent. in a two-year follow-up period.

Does this justify the easier simplified procedure?

In dealing with the young active age group, I do not believe we can compromise. We know that the incidence of recurrence falls off sharply in patients over forty-five years of age and, therefore, in this group there may be some justification for an easier method, particularly when a long, difficult operation is not desirable. However, in the younger, more active group in whom the incidence of recurrence is highest, we are obligated to do the best job, whether it is difficult or not.

What is considered a reliable procedure?

Follow-up studies since World War II have given us a better idea of the efficiency of various methods of repair in general use today.

Gallie and Le Mesurier [b] reported 4.0 per cent. recurrences in 175 patients treated by the fascial-repair method. J. C. Adams reported 5.4 per cent. recurrences in patients operated on by the Putti-Platt procedure [a], and 5.5 per cent. recurrences in patients operated on by the Bankart procedure. Palmer and Widén reported 6.7 per cent. recurrence in their bone-block procedure [c].

In a twenty-year follow-up period, there have been no recurrences to date in our series of seventy-five patients treated by the Bankart procedure at the Massachusetts General Hospital. In other words we may say that any procedure with a recurrence rate greater than 5 to 6 per cent. is beginning to fall below an average standard rate.

Follow-up studies covering a two-year period must also be evaluated in proper perspective. In analyzing the cases of shoulder dislocation at the Massachusetts General Hospital, we found an interesting pattern of recurrence following various methods of repair other than the Bankart procedure.

In 52 per cent., dislocation recurred within two years after operation.

In 18 per cent., dislocation recurred between two and five years after operation.

In 30 per cent., dislocation recurred between five and twenty years after operation. These figures have prompted us to longer follow-up studies.

Col. Brav's operative findings of significant trauma to the cartilaginous labrum and the glenoid rim and of defects in the humeral head are similar to other reported figures. The incidence he reports of 27 per cent. recurrences in shoulders which did not have a history of initial trauma seems a little high.

I would like to ask Col. Brav whether he re-operated on any of his patients with postoperative recurrences, in an effort to find out why dislocation recurred.

I have enjoyed reviewing Col. Brav's paper and thank him for the added information on shoulder repair which he has given us.

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Dr. Paul B. Magnuson, Chicago, Illinois: I have enjoyed Col. Brav's presentation, and I think it is a very good modification of a procedure which aims to be what every operation for recurrent dislocation of the shoulder ought to be. The object should be active support around the head of the humerus. In my experience, the most logical way to provide active support is to transpose the insertion of the subscapularis muscle and tendon to fit snugly around the anterior and inferior surfaces of the humeral head. This provides an active force which pulls the humerus back into its normal position and counteracts the active dislocating force which is downward and forward.

I feel that the capsule of the shoulder joint has nothing whatsoever to do with holding the head of the humerus in the glenoid. We have all seen the looseness of the capsule in cases of paralysis of the deltoid muscle. It is a loose capsule which allows for the wide range of shoulder motion. The glenoid lip or glenoid labrum has nothing to do with holding the head of the humerus in the joint. The lip may have broken off or almost anything else may have happened to it, and still there may not be any dislocation; all that it constitutes is a fulcrum on which the head of the humerus can be moved by the muscles.

To me, success in any operation for recurrent dislocation of the shoulder depends upon supplying this active force for pulling the head of the humerus backward and upward into the glenoid fossa.

The operation which Dr. Stack and I described in 1941 was designed to provide this active force by making use of the subscapularis muscle. The objective of the operation is the formation of a cup of muscle or tendon around the lower and anterior part of the head of the humerus. The cup of tendon is fastened in a position which will not allow the tendon to slip up between the head of the humerus and the coracoid process when the dislocating force is applied. It will also resist the downward and forward pull of the pectoralis major, latissimus dorsi, and teres major which tend to pull the head of the humerus off the relatively flat surface of the glenoid.

The operation is done through the anterior approach. The subscapularis tendon is identified and its borders above and below are freed. The incisions follow the tendon medially, from its attachment on the medial border of the bicipital groove, to the musculotendinous junction. The tendon is detached with a wedge of bone from its insertion at the bicipital groove. The tendon insertion with its wedge of bone is then retracted anteriorly and medially, which exposes the anterior part of the humeral head and the glenoid rim more easily than any other way.

The tendon is then pulled around to the greater tuberosity with the arm in internal rotation. A site for attachment is selected between the tuberosity and the upper portion of the shaft of the humerus, just below the head, which will allow for the best support. This is usually in the cancellous portion of bone. In some instances, a narrow tendon, which is not closely attached to the capsule, is found. In such instances, the subscapularis is pulled or stretched to form a cup around the head of the humerus and sutured as far down as possible so that it cannot slip up between the humerus and the coracoid process.

At the selected point, a wedge-shaped longitudinal gutter is made in the humerus with a chisel. The subscapularis tendon is attached to the humerus by fitting the wedge-shaped bone into the gutter and suturing it in place. The tendon may be sutured to the capsule or to the external rotator cuff for reinforcement.

The point of the attachment is selected by determining the portion of the anterior and inferior part of the head of the humerus which will best be supported by the tendinous cup against the thrust which causes dislocation. It is a mistake to attach the tendon to the greater tuberosity. I have seen a number of tendons which, after attachment in this way, have slipped up between the coracoid process and the head of the humerus when the arm was in a position of abduction and external rotation.

The type of operation done is of little importance; this is the principle that I believe is necessary in order to prevent redislocation. The Bankart operation appeals to me just about as much as the one which T. Turner Thomas used to do when I was an intern. We always said that, if there were enough adhesions or an infection to limit the motion of the shoulder, a cure resulted. Otherwise, the dislocation recurs. The Bankart operation subjects the patient to a lot of unnecessary surgery in my opinion. I think Col. Brav's modification of the Putti-Platt operation is all right; the principle is the same as in this operation, but plication of the tendon is more difficult to do. If the muscle insertion is transposed so that a cup is formed under and anterior to the head of the humerus, then, when the arm goes upward and backward, the subscapularis muscle will hold the head of the humerus back actively.

I was interested to hear what Col. Brav said about the right-sided dislocations in left-handed people and left-sided dislocations in right-handed people. It may be that the muscle control and dexterity of the arm which is used most may account for the incidence of dislocation being lower than in the less dexterous arm in which there may be poor coordination.

All of the operations that I performed in a series of six patients with recurrent dislocation of the shoulder were 100 per cent. successful. Some of the patients had had three recurrences They have had no recurrences since operation.

I would like to know what limitation of the shoulder there is after any of these operations which Col. Brav has described. I would like to know how many of these patients reported by Dr. Rowe can get their shoulders up into the position which favors dislocation.

(Continued on page 846)

EXPERIMENTAL BONE TRANSPLANTS * †

BY ROBERT S. SIFFERT, M.D., NEW YORK, N. Y.

From the Departments of Orthopaedic Surgery and Pathology, Mount Sinai Hospital, New York

The development of bone-grafting techniques during the last decade has made feasible many extensive and major reparative and reconstructive orthopaedic procedures. Autogenous and homogenous bone grafts have been used in either fresh or frozen states to bridge defects and to assist in the healing of ununited fractures and in the arthrodesis of joints. Much experimental work has been done, and many specimens removed operatively have been examined in an attempt to gain a better understanding of the process of bone healing in the presence of bone grafts. In the broadest descriptive sense, there is a simultaneous piecemeal removal and replacement of the transplanted fragments. Autogenous iliac grafts have been shown to be superior to dense tibial grafts, primarily for architectural reasons [4, 9], the cancellous structure of iliac bone presenting more abundant avenues for easier and quicker invasion by new bone. Some investigators have demonstrated continued growth from viable transplanted endosteal elements [1, 25], while others have insisted that all transplanted fragments become necrotic [2, 14]. Transplants have been variously interpreted as forming a passive scaffolding for new-bone growth, and as active stimulators of osteogenesis [11, 13, 22]. Furthermore, there has been disagreement as to whether homogenous bone is incorporated as rapidly as autogenous bone [3, 23, 32], as to the eventual fate of the transplanted fragments in the process of incorporation, and as to the role of alkaline phosphatase [28], tissue fluids [8], and bone salts [15, 24].

The present study reports the results of autogenous, homogenous, and heterogenous bone grafts in rabbits as compared to results of autogenous shave and callus transplants.

METHODS

The experimental animal used was the rabbit. For uniformity, both donor and host animals were selected which weighed between 2.0 and 2.5 kilograms, being only a few months old, and which were of the Chinchilla or New Zealand breed.

The host site was either the ulna or the gluteal muscle. In the former, a 1.0 centimeter defect was made subperiosteally in the ulna, about 1.0 to 1.5 centimeters above the distal epiphyseal plate (Figs. 10-A, 10-B, and 10-C). This site was chosen because of ease of access and because plaster immobilization was unnecessary, since the interosseous membrane of the rabbit is partially ossified. Grafts were placed into the defects, which were created with a sharp clipper or a rotating saw blade, and were held in position by suturing of the overlying soft tissues with cotton. A small quantity of sulfanilamide subcutaneously and a single dose of 300,000 units of procaine penicillin intramuscularly aided materially in preventing infection. In transplantations to the gluteal muscles, a point was chosen mid-way between the posterior iliac spine and the greater trochanter of the femur, the animal being held prone with the lower limbs extended. Muscle fibers were spread with an artery clamp and the graft was inserted into the muscle. A single cotton or silk suture held the graft in place, and served as a marker for the localization of the graft site after the animal had been sacrificed.

A total of 157 transplantations were performed. Donor material consisted of iliac transplants, cortical slivers, cortical shave grafts, and callus.

1. *Iliac transplants:* Thirty-four iliac grafts (twenty-two autogenous and twelve

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homogenous) were placed in ulnar defects and eight autogenous grafts were placed in the gluteal muscle. In all instances the iliac apophysis was easily removed and a large amount of iliac bone was readily available. Full-thickness slices from the ilium were removed and were split through the cancellous portion, and transplants were fashioned to contain either pure cancellous bone or both cancellous and cortical iliac bone. Thin slivers, usually measuring from one third to one half the length of the defect, were used as transplants.

2. *Cortical transplants:* Twenty-six tibial grafts were transferred to the ulnar defects (twelve autogenous and fourteen homogenous). Fragments (approximately the size of the iliac transplants) were removed subperiosteally with a small dental osteotome. In addition, eighteen heterogenous tibial fragments approximately the same size were transplanted from dogs' tibiae to the rabbit ulnae.

3. *Cortical shave grafts:* Twenty-four autogenous shave grafts were placed in ulnar defects. These were fine-curled shaves obtained, by means of a small carpenter's paint scraper, from the subcutaneous surface of the tibia which had been stripped of its periosteum.

4. *Callus transplants:* Nine transplantations of autogenous callus to ulnar defects and thirty-eight transplantations of autogenous callus to the gluteal muscle were performed. Callus was obtained by creating a 1.0 centimeter defect subperiosteally in the ulna of a rabbit. At reoperation one, two, three, and four weeks later the contents of the defect were removed and were transplanted autogenously to a fresh defect in the opposite ulna, or were placed autogenously into the gluteal muscles. At one week the defect in the donor bone contained primarily granulation tissue, at two weeks it contained soft callus, and at three and four weeks it was occupied by bone.

In the section in which the results of shave grafts are described, preliminary observations of *in vitro* experiments are discussed, since they suggest steps in the mechanism of destruction of this type of graft. Slivers of tibial bone were decalcified in a solution of 5 per cent. nitric acid or 5 per cent. formic acid. They were then incubated at 38 degrees centigrade in a 5 per cent. pepsin solution in one-tenth normal hydrochloric acid for periods varying from the first appearance of translucency to almost complete digestion, with fraying of the fragments. The specimens were then fixed in 10 per cent. formalin and were sectioned and stained for collagen as described below. Commercial gelatin was dissolved and a thin film was painted on slides and was stained in a like manner. Gelatin was also prepared from rabbit collagen by boiling tendon and concentrating the filtrate by evaporation. Commercial gelatin and that derived by hydrolysis from rabbit collagen appeared identical when stained.

This report is concerned with the earliest stages of graft incorporation, the transplants being studied at weekly intervals during the first six weeks of healing. The techniques used in the evaluation of specimens were as follows:

1. Routine hematoxylin and eosin stains were made.
2. Van Gieson stains for collagen were made.
3. Alkaline phosphatase stains were made according to the principles of Gomori as applied to bone by Lorch, Greep and his associates, and McKelvie.
4. The localization of phosphates was demonstrated by adding 1 per cent. cobalt nitrate to the fixing solution (10 per cent. formalin buffered at neutral) to precipitate the soluble phosphates. The insoluble cobalt phosphates so formed were then transformed into cobalt sulphides and visualized as black deposits. In order to avoid liberation of phosphates by postmortem phosphatase activity, only specimens obtained immediately after sacrifice of the animal were studied. This technique is based on the principle of the Gomori phosphatase controls, and its accuracy as a method for localizing phosphates was confirmed by studies using radio-active phosphorus (P^{32})[27].
5. The progress of the removal and replacement of the graft was evaluated by roentgenographic studies.

RESULTS

1. *Bone Transplants to Defects in the Ulna*

Fibrin clot and organizing hematoma formation occurred in the bone defect, being histologically similar to that noted at a fracture site, and loosely binding the transplanted fragments to the bed. By the end of seven to ten days, granulation tissue growing in from the bone ends replaced the clot and came to surround all of the fragments. The more central portions of the bed then consisted of granulation tissue alone, whereas at the borders of the bed the granulation tissue was giving way to a relatively undifferentiated mesenchymal tissue which appeared to arise from the endosteal elements within the marrow spaces of the host bone. It was within this undifferentiated mesenchymal tissue that callus and new-bone formation occurred. It did not arise *de novo* within the graft bed, but rather invaded the bed from the bone ends and periosteum. In cases in which invasion of the graft bed by callus was delayed (as in the controls in which no graft was used), in wide defects, in the presence of heterogenous transplants, and apparently when excessive motion was present between the fragments because of disruption of the ossified interosseous membrane, non-union and delayed union were noted. This faulty union was associated with the transformation of the multipotential undifferentiated mesenchyme into relatively dense connective tissue, which acted as a mechanical barrier to new-bone formation [29].

Early healing occurred through the formation of approximately equal quantities of cartilaginous and fibrous callus. The primitive mesenchymal tissue, often within the same microscopic field, exhibited the potentiality to be transformed into both of these types of pre-osseous tissue[21]. The two forms of callus, however, went on to bone formation in different ways. As the cartilage cells formed, usually in nests, they showed great similarity to the cartilage cells seen in the zone of proliferation in the growth columns of either epiphyseal or apophyseal lines. Although the arrangement was not as orderly, there was often the suggestion of palisading of cartilage cells as they underwent enlargement and swelling, with the deposition of large amounts of alkaline phosphatase in the intercellular matrix [28] (Fig. 1). Ingrowth of vessels and osteoblasts and the formation of bone trabeculae occurred often in a fashion identical to that seen in epiphyseal ossification. However, much less inclusion of cartilage remnants in the newly formed bone trabeculae was noted as compared to the large cartilage remnants in metaphyseal new bone. In contrast, bone forming by metaplasia directly from undifferentiated mesenchymal tissue, or "fibrocallus", did not pass through the preliminary phase of tissue formation and destruction which occurred in cartilage callus. Fine fibrils of collagen, staining bright red with the van Gieson technique, were observed in the maturing mesenchymal tissue. As the cells matured and became larger and more darkly staining, the collagen fibers between them became denser, and coalesced to form the primary bone trabeculae. The cells themselves either became entrapped in this fibrillar new bone, or applied themselves to the surfaces of these trabeculae as osteoblasts. The denser mesenchymal tissue or young fibrous tissue remaining between the newly formed trabeculae served as the principal avenues through which vascular channels grew during the invasion and remodeling of the primary trabeculae. In some areas isolated random trabeculae formed in this fashion, while in other areas a more orderly formation of bone could be seen originating from a condensed sheet of cambium-like mesenchyme, simulating subperiosteal new-bone growth (Fig. 2).

In the young undifferentiated mesenchyme, alkaline phosphatase was almost completely absent. As differentiation into pre-osseous tissue occurred (cartilaginous and fibrous callus), there was dense alkaline phosphatase deposition in the intercellular material (Fig. 1). Along the surfaces of the newly formed trabeculae, and along invading vascular channels, where young osteoblasts were proliferating, both alkaline phosphatase

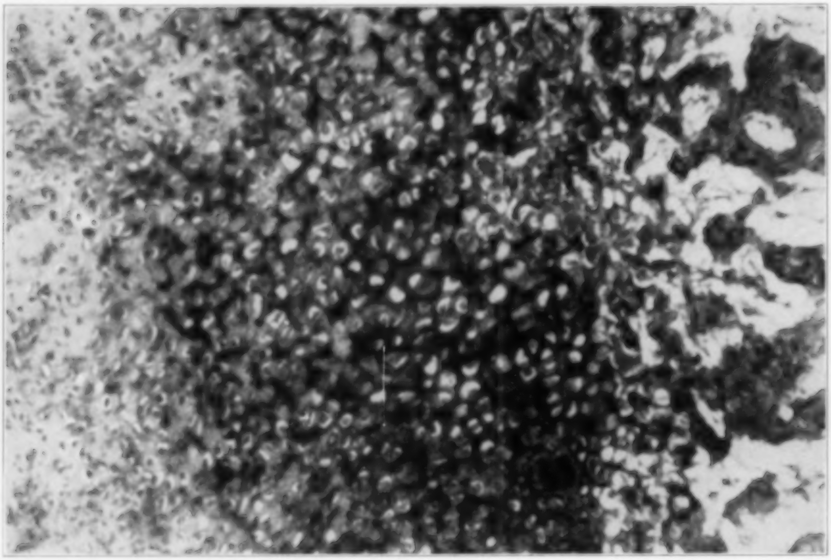

FIG. 1

Photomicrograph (× 90) of a section of cartilaginous callus in a graft bed being transformed into bone (stained for alkaline phosphatase). Although the process is not as orderly as in epiphyseal ossification, there is a similar enlargement of cartilage cells, with deposition of alkaline phosphatase in the intercellular matrix, and invasion and destruction of the cartilage cells by vascular channels and osteoblasts, with the formation of new-bone trabeculae.

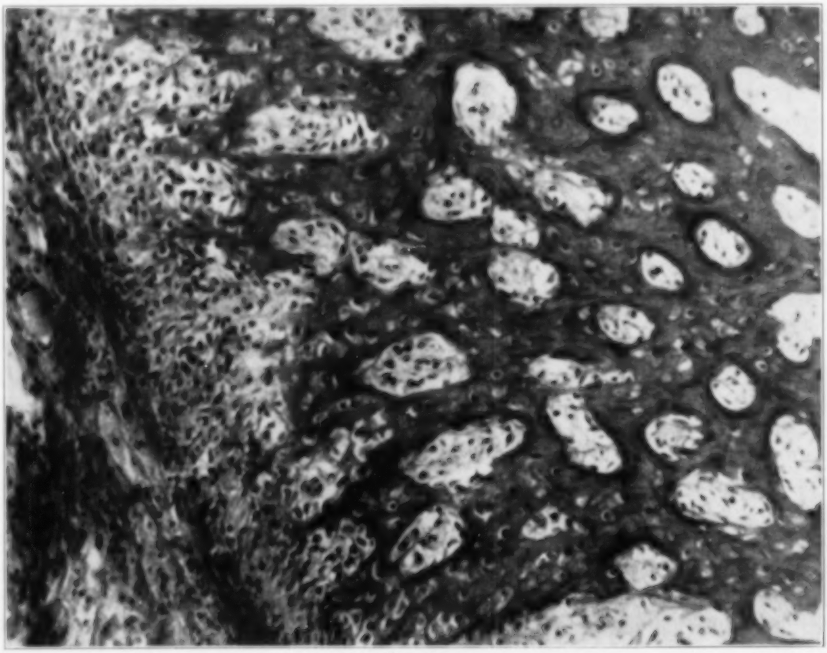

FIG. 2

Photomicrograph (× 105) of a section showing new-bone formation by direct transformation from the mesenchymal tissue. A cambium-like sheet has condensed within the callus bed and cells arising from it are being transformed into osteoblasts. The new bone is being formed by the deposition of collagen and matrix between these cells, the cytoplasm of which contains no collagenous material. (Van Gieson stain.)

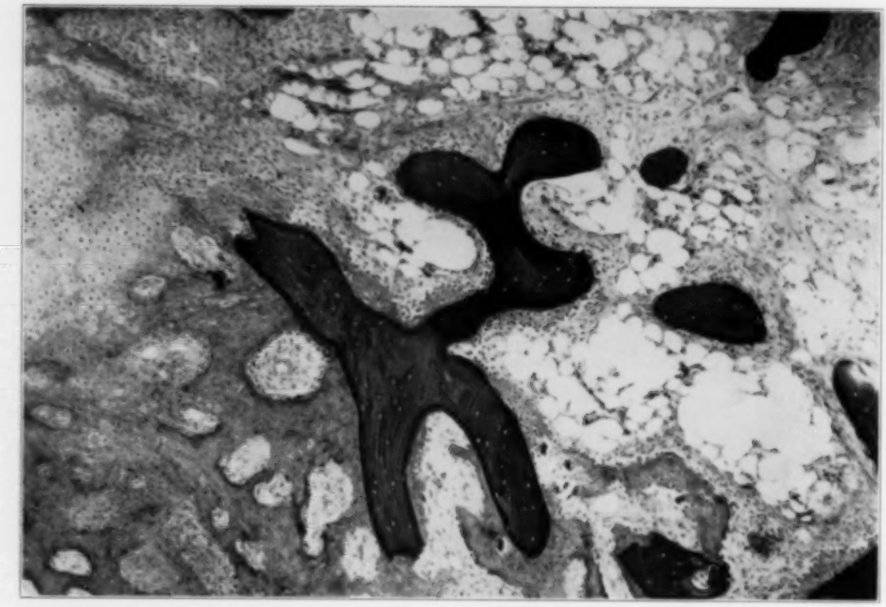

FIG. 3

Photomicrograph (× 70) showing autogenous cancellous bone two weeks after transplantation to the ulnar defect of a rabbit. The new bone, growing in appositional fashion along the surfaces of the necrotic transplant, has its origin from the invading bone growing in from the bone ends. Isolated sections, including necrotic trabeculae and appositional bone, are often misinterpreted as surviving and proliferating endosteum. The bone growing along the trabecular surface is in advance of that in the surrounding bed. The transplanted marrow is necrotic. (Reproduced by permission from *New York State Journal of Medicine*, **52**: 3021, 1952.)

and phosphates were demonstrable. The enzyme usually co-existed with the salt along the surfaces of new trabeculae. However, it was not uncommon to notice phosphate deposition occurring after the enzyme had reached its maximum activity, and often after non-calcified matrix had been deposited. In the cartilaginous callus, as has been observed in epiphyseal plates [28], phosphatase usually appeared in advance of phosphate deposition.

A. *Autogenous and homogenous transplants:* In this group of experiments there was no evidence that any of the transplanted iliac or tibial fragments survived. Trabeculae close to the bone ends often exhibited a row of osteoblasts on their surfaces (Fig. 3). The lacunae of the trabeculae were either empty or contained pyknotic nuclei of necrotic osteocytes. In all instances the surface osteoblasts were the result of appositional growth and were not surviving cells. Proliferating surface osteoblasts were never present during the first week, at which time the bed consisted of granulation tissue and fibrin clot. They appeared only when the bed was being transformed into one containing immature mesenchymal tissue, and only when new bone began to grow in from the endosteum and periosteum of the bone ends. It would seem that, if the graft trabeculae which exhibited appositional osteoblasts were surviving, this would be apparent during the first week after operation, as was the case in the experiments in which bone was transplanted to muscle and actually did retain its viability and proliferate. An appositional osteoblastic layer, indistinguishable from that seen in the autogenous grafts, was often noted on the universally necrotic homogenous transplant fragments. When adjacent areas within a block were studied, spearheads of bone were easily identified as invading the field from a different level of the block, where callus formation was abundant. Individual plane sections often gave the erroneous impression that the appositional growth was due to proliferation of surviving osteoblasts.

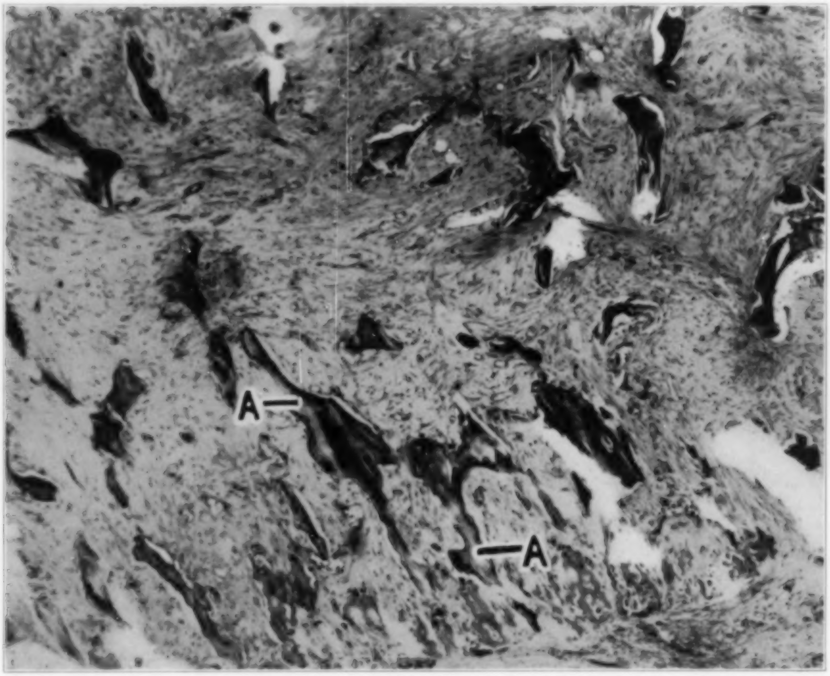

FIG. 4

Photomicrograph (× 65) showing autogenous metaphyseal fragments two weeks after transplantation to the ulnar defect of a rabbit. The fragments contain remnants of epiphyseal cartilage (*A*) which stain heavily for alkaline phosphatase. There is no evidence of bone or collagen formation, phosphate or phosphatase deposition, in the areas where the cartilage remnants contact the immature mesenchymal tissue of the graft bed.

The type of bone transplanted played an important role in the way in which the graft was incorporated. Autogenous grafts were rapidly surrounded by young healthy vascular mesenchymal tissue. Although there were many instances in which it was impossible to discern a difference between autogenous and homogenous grafts, in the latter bone growth was generally more sparse within the graft bed. The autogenous grafts were rapidly invaded by vascular channels, and were replaced by new bone relatively quickly. Homogenous grafts were generally revascularized more slowly. In heterogenous transplants of dog bone to rabbits there was very sparse new-bone growth from the bone ends, complete lack of incorporation of the fragments, and a tendency toward the development of a denser mesenchymal tissue in the graft bed. The bed in the homogenous and autogenous transplants appeared identical. Marrow tissue which had been transplanted with cancellous grafts always became necrotic, often acting as a real barrier to the invading bone in the same manner as did interposed muscle and fat.

Although autogenous transplants were tolerated best, there was no indication at any time that the fragments themselves acted as a direct stimulus to osteogenesis. New-bone formation did not occur in proximity to any of the grafts in advance of the penetrating pseudopods of bone and cartilage. Even when the transplanted bone contained metaphyseal cartilage remnants or callus rich in phosphatase, there was no visible change in the graft bed or evidence of bone formation, such as the development of matrix, collagen deposition, or calcification (Fig. 4). Supporting the concept that bone constituents themselves are not osteogenetic in the sense of causing direct stimulation of new-bone formation from the graft bed was the fact that the only local reaction to necrotic fragments was an osteoclastic and fibroplastic one. In general, Howship's lacunae were more

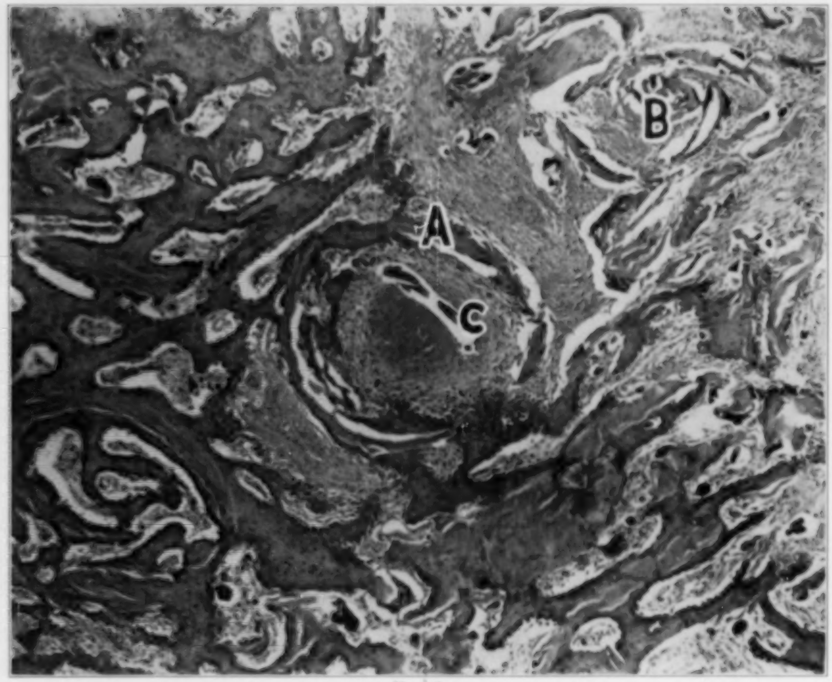

Fig. 5

Photomicrograph (× 65) showing autogenous tibial shave grafts two weeks after transplantation to the ulnar defect of a rabbit. The shave graft (*A*), which offers large surface areas, is readily surrounded by invading new bone when it is located near the cut bone ends. Even in this location of exuberant osteogenesis, extensive osteoclastic reaction has already begun, with destruction of some of the shaves (*B*) and partial destruction of those shaves that are being surrounded by appositional new bone (*C*).

common along the borders of cortical chips than along the borders of cancellous trabeculae. They were also more common along the cut borders of the trabeculae of cancellous grafts than along the intact surfaces.

The surfaces of the transplant appeared to serve primarily as a scaffolding and surface guide for new-bone formation. Appositional bone was a virtual spearhead of osteogenesis creeping along the borders of the transplants far in advance of bone formation in the adjacent bed (Fig. 3). It passed in "hedge-hop" fashion from one fragment to another, often bridging the defects along the borders of the grafts, while the rest of the bed still consisted of early callus. The remaining bed was rapidly invaded as bone spread out from the surfaces of the transplant. From the architectural viewpoint, the larger the absolute surface area of transplanted bone, the more avenues for appositional growth existed. Cancellous grafts, with intact surfaces and structural continuity, provided large surface areas in relation to their volume and were architecturally ideal as grafting material.

B. *Shave grafts:* Since more rapid bone growth occurred in graft beds containing iliac grafts than in those containing tibial grafts, presumably because of the large surface areas available for appositional growth in the former, it seemed theoretically possible that even better surface areas of autogenous bone might serve as scaffolds for new-bone formation. Shave transplants appeared to be ideal for this purpose, since they were autogenous and presented large surface areas. However, the same autogenous tibial bone which was well tolerated and created little or no tissue reaction in the immature mesenchymal graft bed when transplated as fragments, caused a totally different response

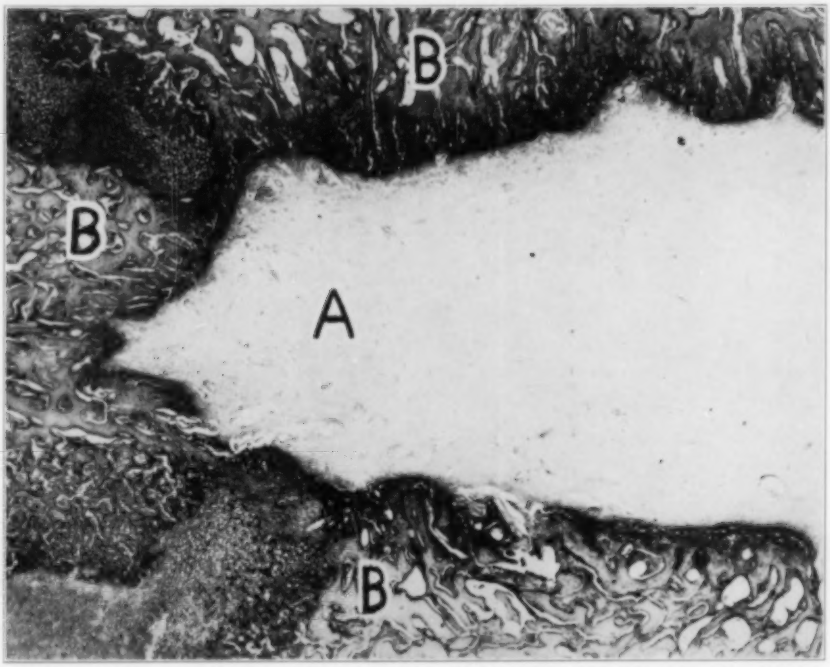

FIG. 6

Photomicrograph (× 30) of shave grafts two weeks after transplantation to the ulnar defect of a rabbit (section stained for alkaline phosphatase). The shave grafts are being destroyed by phagocytosis in a fibroplastic bed (*A*) which, because of its lack of osteogenetic response, stains lightly for phosphatase. This shave-graft bed is separated by a "pseudocapsule" of dense connective tissue from the richly staining, phosphatase-positive osteogenetic bed of invading new bone from the periosteum and bone ends (*B*). (Reproduced by permission from *New York State Journal of Medicine*, **52:** 3023, 1952.)

when converted into fine-curled shaves. The shaves were rapidly surrounded by clot and young granulation tissue. At the fractured ends, where early exuberant new-bone formation was evident, the potentiality for osteogenesis was similar to that noted in other autogenous grafts. Occasional shaves in this peripheral location were rapidly surrounded by newly formed bone trabeculae and were later replaced in the remodeling process together with the primary new-bone trabeculae (Fig. 5). However, the overwhelming majority of the shaves incited a strong foreign-body reaction. This was particularly true of those that were more remote from the bone ends and remained in contact with the granulation and immature mesenchymal tissue of the early differentiating graft bed for the longest period of time. This foreign-body reaction was similar to that noted in the formation of Howship's lacunae at the cut surfaces of the transplants, but was of much greater intensity. The shave surfaces were attacked by large numbers of osteoclasts and the grafts were eventually phagocytized in a manner similar to the phagocytosis of necrotic bone fragments noted in the experiments of Urist and McLean [30]. In these areas of reaction, a dense connective-tissue bed formed in place of the loose immature mesenchymal tissue of well tolerated grafts. A "pseudocapsule" of dense connective tissue surrounded the shaves and separated them from the rest of the graft bed (Figs. 6 and 7). Only after the shaves became fully phagocytized did the capsule and fibrous bed shrink and the area was then invaded by new bone. The shaves were therefore completely destroyed as foreign material, playing no role in bone formation except for those few which were contacted very early by mesenchymal tissue at the periphery of the bed,

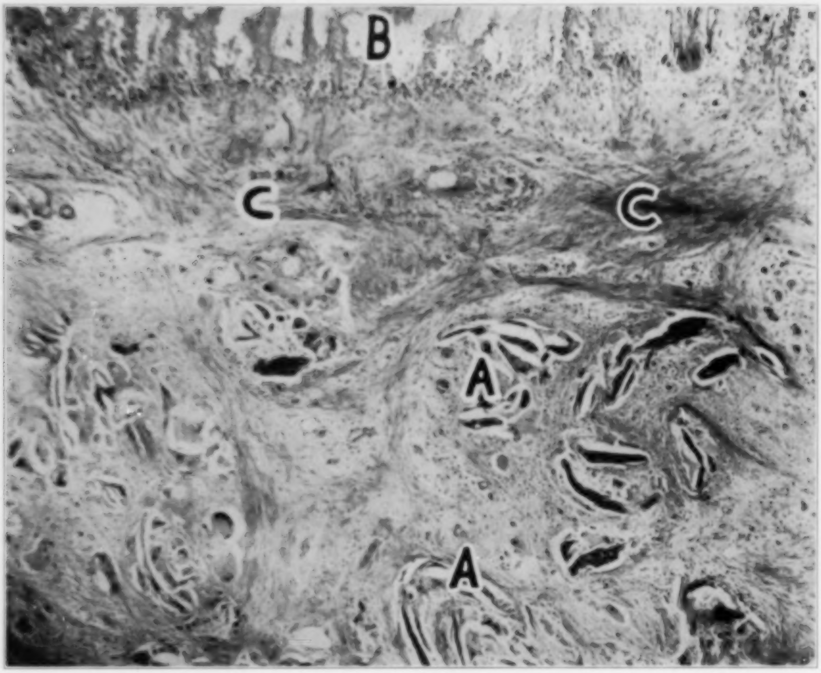

FIG. 7

Photomicrograph (× 65) of shave grafts two weeks after transplantation to the ulnar defect of a rabbit. The shaves (*A*) are being destroyed by phagocytosis in a bed of dense connective tissue created by a fibroplastic reaction to the grafts. The shave-graft bed is separated from the invading new bone (*B*) by a "pseudocapsule" of dense connective tissue (*C*). (Reproduced by permission from *New York State Journal of Medicine*, **52:** 3023, 1952.)

before tissue reactions were mobilized. In fact, the shaves impeded healing by inciting osteoclastic and fibroplastic reactions.

The destruction of shaves occurred mainly by phagocytosis. Various-sized fragments of bone, many still calcified, could often be identified within the confines of the osteoclasts. These fragments, as well as many outside of these cells, were being destroyed apparently by proteolytic digestion. There was loss of the bright-pink-staining qualities of the collagen fibers with the van Gieson stain, then loss of distinct fiber architecture, and finally the transformation of the fragment into a faintly pink vacuolated mass, indistinguishable from gelatin, which is the hydrolysate of collagen (Fig. 8). These fragments were identical in appearance to stained commercial and extracted rabbit gelatin, and to rabbit cortical bone digested *in vitro* by incubation in a pepsin solution as described (Figs. 9-A and 9-B). In fact, the appearance of the bone during the various stages of proteolytic digestion by pepsin *in vitro* was identical to that of the shave fragments undergoing destruction within the osteoclasts or in the tissue bed in the presence of osteoclasts. Further studies are indicated to clarify the role played by the osteoclasts in the proteolytic digestion of bone, and to determine whether this cell is involved in the extracellular digestion of bone, or whether digestion occurs solely through the action of tissue fluids [8].

Once healing across the defect had occurred and each fragment was surrounded by new bone, the remodeling process took place. In the trabeculae of cancellous bone, invasion, destruction, and replacement were more rapid than in cortical fragments, many of which were so dense as to be still recognizable by their former outlines and by the absence of phosphatase late in the remodeling process. It appeared to be not only the small size

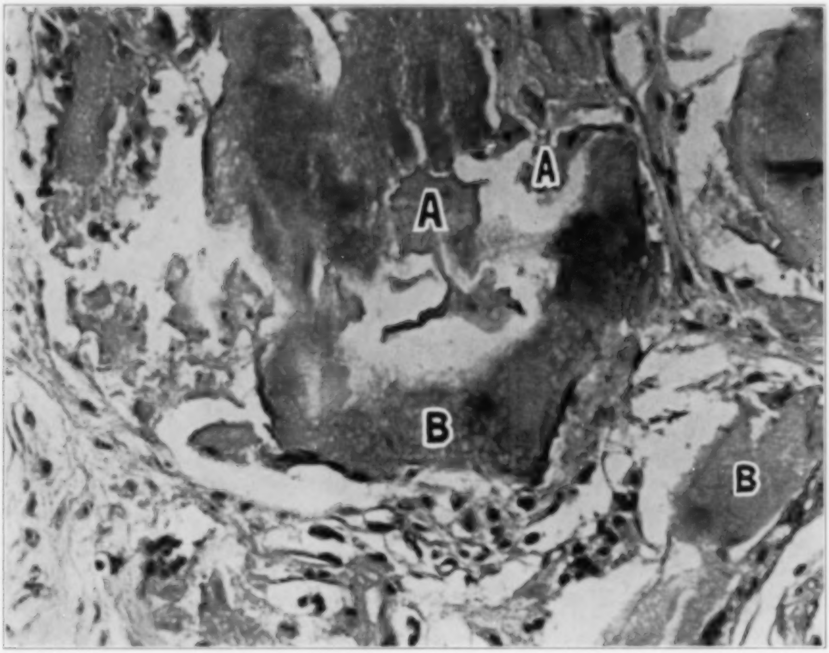

FIG. 8

Photomicrograph (× 197) of shave grafts three weeks after transplantation to the ulnar defect of a rabbit. (Stained by the van Gieson technique.) In the presence of giant cells (*A*), shave fragments (*B*) are undergoing digestion and vacuolation. The collagen fibers in the matrix of the transplanted fragments have been digested, and the matrix itself has taken on a vacuolated appearance identical to the *in vitro* digested bone (Fig. 9-A) and melted gelatin (Fig. 9-B).

of trabeculae of the cancellous grafts, but also their simple vascular structure compared to the complex Haversian systems of cortical bone that facilitated rapid replacement. The ever-continuing, simultaneous removal and deposition of bone in a piecemeal fashion persisted until remodeling was completed. In homogenous grafts there was a delay in the revascularization of the channels of the transplant and in the entire process of remodeling as compared to the autogenous grafts. In the relatively short postoperative period studied — six weeks — there was no bone growth around the heterogenous grafts and no invasion of the vascular channels. Bone growth from the fractured ends of the host bone was slow, and the graft bed contained a more cellular and more fibrous mesenchymal tissue than was seen in the homogenous and autogenous transplants.

In the roentgenographic studies, the bone defect containing iliac grafts was rapidly bridged by a large quantity of homogeneous new bone (Fig. 10-A). Less exuberant new-bone formation occurred in the presence of tibial fragments (Fig. 10-B). The failure of incorporation of the shave grafts was clearly demonstrable on roentgenograms, in which the mass of shaves appeared like a central sequestrum, while the defect was bridged by surrounding new bone forming from the periosteum and endosteum of the host (Fig. 10-C).

2. *Autogenous Iliac-Bone Transplants to Muscle*

Specimens of iliac bone transplanted to the gluteal muscle and recovered at the end of one week showed that almost all of the bone elements were necrotic. The lacunae were either empty or contained pyknotic nuclei. There was little or no giant-cell reaction to the bone. Moderate amounts of alkaline phosphatase were present in the young con-

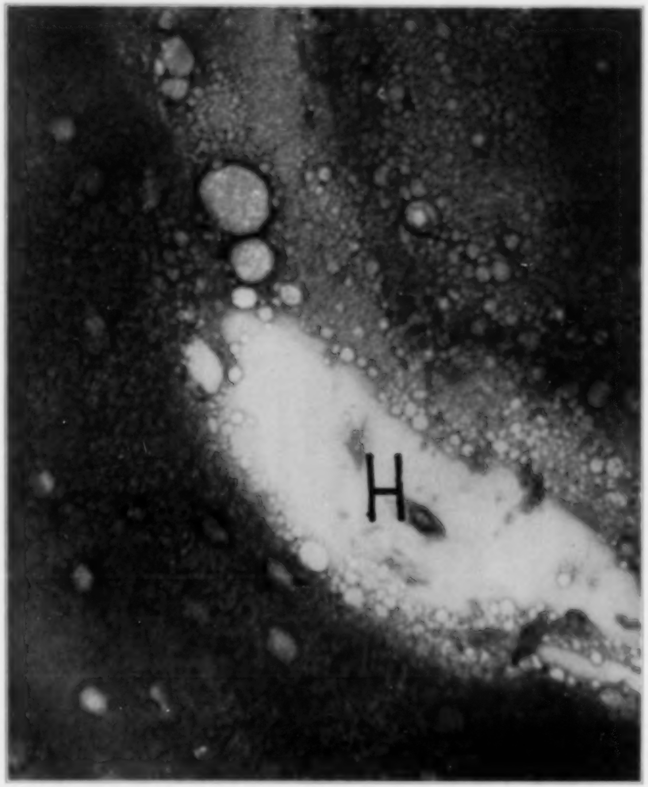

Fig. 9-A

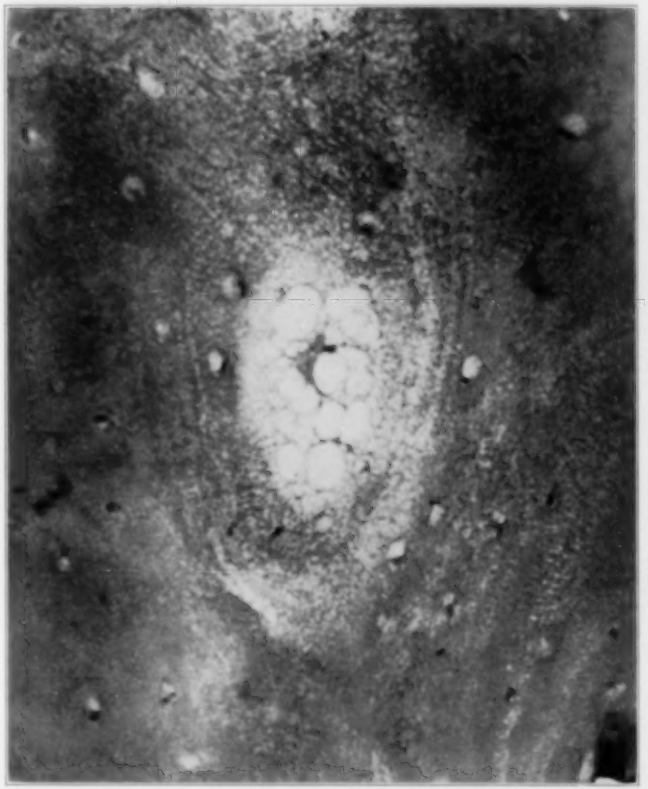

Fig. 9-B

Fig. 9-A: Photomicrograph (× 475) of a section from an adult cortical rabbit bone digested in a solution of pepsin and hydrochloric acid and stained by the van Gieson technique. Note the vacuolation of the matrix, which is being completely digested and dissolved at the borders of the Haversian canals (*H*), where direct contact is made with the digesting solution. The collagen fibers have been completely digested and the matrix has taken on the appearance of gelatin.

Fig. 9-B: Photomicrograph (× 475) of a section of melted gelatin stained by the van Gieson technique. The vacuolated structure is indistinguishable from the appearance of pepsin-digested bone shown in Fig. 9-A.

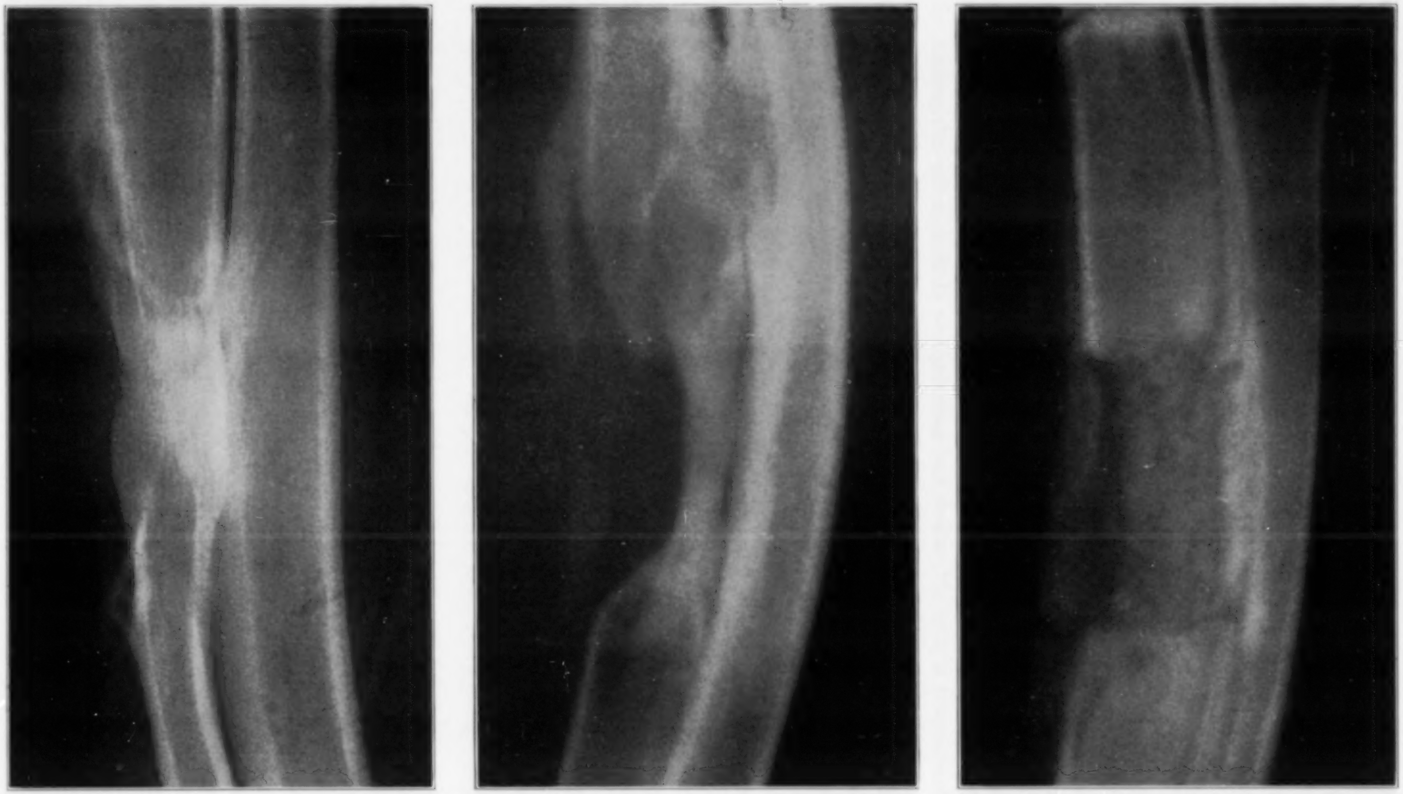

Fig. 10-A Fig. 10-B Fig. 10-C

Roentgenograms made three weeks after transplantation of bone grafts to the ulna of a rabbit.

Fig. 10-A: Autogenous cancellous graft, showing exuberant bone formation and a homogeneous bed, indicating rapid incorporation of the bone grafts.

Fig. 10-B: Autogenous tibial graft, indicating sparse bone formation along the surface of the tibial graft.

Fig. 10-C: Shave grafts unincorporated and surrounded by sparse subperiosteal new bone.

nective tissue of the healing wound, but there were no signs of new-bone formation in this tissue. In the peripheral areas of the transplant new bone was forming on the surface of the necrotic trabeculae. It represented surviving and proliferating endosteal cells since there were no immature osseous elements in the surrounding mesenchymal tissue of the graft bed.

At the end of two weeks in the muscle bed, there was a denser deposition of connective tissue and collagen in the intertrabecular spaces, as well as around the transplant, indicating the formation of a loose capsule which separated the graft from the surrounding muscle bed. The endosteal seams were much larger than those noted at the end of one week, and had spread to a larger area of the necrotic bone surface. As in the one-week-old sections, there was no new-bone formation *de novo* within the surrounding tissues. The transplanted marrow and resting elements within the graft were necrotic. The occasional nuclei seen within the transplanted lacunae were interpreted as being necrotic or on the borderline of viability, since in later specimens all nuclei were absent. The presence or absence of alkaline phosphatase was not a reliable guide as to the viability of the tissues, since the enzyme was noted to remain unchanged for weeks in necrotic areas, such as in callus transplants or in cartilage remnants of metaphyseal bone. In some specimens over a year old, which had been kept in alcohol in the refrigerator, alkaline phosphatase was demonstrable in amounts apparently almost as large as was noted in the fresh specimens. In transplants containing cartilage fragments from the growth lines of iliac apophyses, there was no evidence that growth continued or that transplanted elements survived.

Sections of transplanted iliac trabeculae implanted in the gluteal muscles for three or four weeks demonstrated increasing osteoid seams and appositional bone growth. Of practical importance is the fact that the quantity of bone growing from the surviving endosteal elements of the transplants to muscle was sparse compared to the exuberant callus formation and appositional bone growth noted in autogenous and homogenous transplants to graft beds. This appears to indicate that in a graft bed, the quantity of new bone arising from the fracture ends and periosteum far outweighs the relatively small amount of new bone which, even under the nearly ideal circumstances existent in a muscle bed, might form from surviving endosteal elements of the transplant. It further supports the thesis that, as far as the over-all healing of the defect is concerned, it is of little importance whether transplant fragments survive in part or become totally necrotic.

3. *Callus Transplanted to Muscle and Bone Defects*

Specimens of callus one, two, three, and four weeks old were removed from a defect in the ulna and transplanted to ulnar defects on the opposite side and to the gluteal muscle in the same animal. Since callus represents all of the stages of new-bone formation, it was thought that it would contain any bone-stimulating or osteogenetic factors which normally play a role in the formation of new bone in a graft bed.

In general, the transplants of callus two, three, and four weeks old to muscle behaved similarly to transplants of mature iliac bone to muscle. The surviving elements were always endosteal cells lining the young bone trabeculae, and new-bone formation stemmed only from proliferation of these cells. No new bone appeared to be formed by the continued proliferation and differentiation of the cartilage or fibrous callus of the young mesenchymal tissue of the transplant, or of the young connective tissue in the host bed. Most of the osteocytes in the young bone trabeculae of the transplanted callus were absent or pyknotic. There was invariably a capsule of connective tissue surrounding the callus transplant and separating it from the adjacent muscle. When one-week-old callus was transplanted, it was absorbed completely since it contained principally granulation tissue, young mesenchyme, and very early fibrous and cartilaginous callus which was easily destroyed by the osteoclasts arising from the inflammatory reaction in the wound. In accordance with the observations made by Urist and McLean [31], new-bone trabeculae in one instance were noted to be developing at the site of fully absorbed callus transplants, suggesting osteogenetic stimulation by elements contained in the early callus which had been transplanted to the muscle bed. The mechanism of this type of stimulation is obscure. There was little difference between two-week-old and three-week-old callus when left in muscle for two or three weeks, except for slightly larger amounts of new-bone formation, and increased fibroplasia of the bed in the experiment continued for three weeks. Four-week-old callus consisted entirely of bone and behaved in a fashion identical to that of the iliac grafts transplanted to muscle. At the end of four weeks in the muscle bed, the fibrous infiltration into the area had progressed still further, and the rate of new-bone formation had diminished to such an extent that almost all of the bone that was seen consisted of young, viable, but no longer proliferating trabeculae. Phagocytosis of most of the isolated dead trabeculae had been accomplished. At the end of three or four weeks, therefore, the turning point seemed to have occurred. It was felt that the absence of functional stress and strain, and the dense fibroplasia and pseudocapsule formation impeding the vascularization of the transplant were in part responsible for the turning point where bone production ceased and bone atrophy began.

When autogenous callus was transplanted to bone defects in the ulna, none of the elements survived, as they did in the transplants to the muscle bed. In fact, the callus, by becoming completely necrotic and failing to stimulate any osteoblastic response from the graft bed, behaved similarly to autogenous iliac bone transplanted to a bone defect. One-week-old callus was completely phagocytized and only a small dense connective-tissue scar remained in the center of the graft bed. Two-week and three-week callus became totally necrotic, causing little osteoclastic or fibroplastic reaction, but its surface served as a scaffolding for appositional new-bone growth. The impression was gained that there was slightly more osteoclastic and fibroplastic reaction along the borders of the callus than along the intact surfaces of autogenous iliac trabeculae.

DISCUSSION

The findings of the present experimental investigation are in accord with the clinical observation that autogenous grafts are incorporated more rapidly than homogenous grafts. In general, the healing of a bone defect in the presence of a fragment of transplanted bone is similar to the healing of a fracture. Small transplanted fragments were surrounded, invaded, and replaced by new bone more rapidly than were larger fragments, purely as the result of their architectural features. In spite of the apparently transient role played by the grafts, they often represented the determining factor in the healing across a bone defect.

These experiments also support the concept that transplants serve primarily as a passive scaffolding or guide wire along which new bone may grow. There was no evidence that the bone-graft beds responded to any direct factor stimulating osteogenesis within the transplants. Necrotic fragments remained completely dormant until they were contacted by the invading trabeculae growing in from the bone ends and periosteum at the margins of the defects. The young mesenchymal tissue of the graft bed which grew around all types of bone fragments retained the same immature qualities as it did in areas remote from the grafts. Phosphates and alkaline phosphatase were identified histologically. There was no evidence that they stimulated new-bone formation locally. Fragments of epiphyseal cartilaginous plates and callus, when transplanted into bone defects, failed to cause new-bone formation in the immature mesenchymal tissue of the graft bed even though rapid bone proliferation was present in both of these transplants. When the proteins of the transplanted bony fragments reacted with the tissue fluids of a graft bed, an osteoclastic rather than an osteoblastic reaction occurred.

Although it is true that autogenous, and in most instances homogenous, grafts augmented new-bone formation as compared to the controls, in which no grafts were used, the nature of this augmentation has not been explained. Invading osteoid and callus gain an impetus to grow when they contact and creep along the surfaces of well tolerated fragments, while no such acceleration of growth occurs along the surfaces of purely inert metal plates. Isolated experiments have demonstrated that an extract of bone, under certain well controlled conditions, may cause bone formation when injected into muscle[18]. A stimulating factor has also been suggested as being responsible for new-bone formation after osseous transplants to the anterior chamber of the eye[31]. However, evidence has not been presented to indicate that a bone-stimulating substance plays a role in osteogenesis in a bone-graft bed.

In the formation of new bone it has been suggested that salts of the transplant might be re-used[30]. It has been suggested by the author[28], and has recently been supported by studies using radio-active materials[5], that in epiphyseal growth local proteins of the pre-osseous cartilaginous tissue might be re-used in the formation of bone trabeculae of the metaphysis. It is possible that, in view of the close chemical relationship between gelatin as a probable intermediate product of bone-protein digestion, and collagen as a principal protein component of bone, some of the proteins derived from destruction of the trabeculae of transplanted bone might be re-used by the osteoblasts in the formation of new bone. There are further experimental data to add support to this hypothesis. In a previous report[28] it was indicated that bone matrix did not appear to be produced within the osteoblast and then secreted, but rather that it was elaborated from materials locally available within the tissue fluids. Huzella demonstrated the production of collagen fibers from tissue fluids and it was further shown[19,26] that similar fibers could be produced from collagen solutions. Both were accomplished by alterations of salt and pH levels in the absence of cells. The close relationship between gelatin and collagen, in addition to their well known chemical similarity, has been repeatedly shown and is easily demonstrable by the transformation of a gelatin pattern to a collagen pattern; this is accomplished by stretching a sheet of gelatin under the roentgen-ray diffraction camera. Studies are in progress to investigate further the possible re-use of bone-graft proteins in the formation of new-bone trabeculae as one of the possible factors responsible for augmentation of bone growth in the presence of graft fragments.

Various investigators have noted that transplanted fragments occasionally survive if they are rapidly revascularized. In the present experiments, the endosteal elements of autogenous iliac bone and callus occasionally survived when transplanted to muscle. The survival of endosteal cells appears to depend solely upon the speed of revascularization of the transplant. They are apparently able to survive in the tissue fluids of the hematoma and of the early granulations of a muscle wound, provided that revascularization occurs soon thereafter. Although survival of these cells (in transplants to bone defects) has never been noted in the present experiments, it is probable that isolated peripheral areas may be revascularized sufficiently rapidly in isolated transplants to sustain the viability of some endosteal cells. However, it appears to be of little practical importance whether these endosteal elements survive or die. In order to survive, they require rapid revascularization in a bed of healthy young mesenchymal tissue very early in the healing process. This type of bed exists only close to the bone ends, where rapid appositional growth on necrotic fragments universally occurs. Both the living and the necrotic trabeculae would then be serving the same function,—that is, they would act as a scaffolding upon which appositional growth of new bone from the living endosteal cells can occur. New-bone formation from the endosteal sites of a fractured bone end was always far more exuberant than that occurring from surviving endosteal elements of iliac bone or callus when the latter was transplanted to a vascular muscle bed.

Alkaline phosphatase has been demonstrated primarily in pre-osseous cartilaginous and fibrous callus, and is always present during the phase of bone-matrix deposition.

Although phosphatase and phosphate deposition are usually concurrent processes, a phosphatase-laden matrix is often demonstrable before phosphates are deposited in both enchondral ossification and callus formation [28]. It appears, therefore, that, although alkaline phosphatase is undoubtedly related to the calcification mechanism liberating phosphates from organic esters, the enzyme is primarily involved in the mechanisms associated with matrix elaboration.

The marked difference in response to the large surface areas of autogenous trabeculated iliac bone as compared to those of autogenous shave grafts from the tibia is striking. Although osteoclasis was noted occasionally in the iliac grafts, chiefly along the cut surfaces, this was the universal response to the shave grafts. Since no physicochemical difference has ever been demonstrated between the osseoproteins of iliac and those of tibial bone, the primary difference between the two grafts appears to be architectural. The surfaces of iliac trabeculae are undisturbed and presumably surrounded by unbroken intertwined layers of dense collagen fibers in the form of circumferential lamellae. Surfaces of shave grafts, however, present large areas of fractured bone, exposing the matrix along with interrupted collagen fibers to the tissue fluids of the graft bed. Since the response to bone protein has been demonstrated to be osteoclastic and fibroplastic, it seems likely that the massive exposure of large fractured bone surfaces is responsible for the massive osteoclastic tissue reaction noted in the shave grafts. In contrast, the relatively slight tissue reaction to iliac grafts and their toleration in a mesenchymal bed with little or no osteoclastic response is probably attributable to their undisturbed architectural structure, with intact circumferential collagen fibers, and the exposure of relatively small amounts of osseoproteins to the tissue fluids of the graft bed. It would account for the apparently greater osteoclasis noted in these experiments at cut ends of trabeculated iliac bone compared to their intact surfaces, and the greater amount of osteoclasis and fibroplasia around transplanted tibial fragments. The slower healing of defects containing cortical as compared to cancellous bone may therefore be due to the relatively smaller total surface areas of tibial grafts available for appositional bone growth and the larger amount of osteoclasis and fibroplasia associated with the cortical grafts which in turn act as barriers to the ingrowth of new bone. The relatively simple vascular network of iliac trabeculae, as opposed to the complicated Haversian systems of dense cortical bone, make cancellous bone as ideal for remodeling as it is in forming scaffolding for appositional bone growth.

CONCLUSIONS

One hundred and fifty-seven bone and callus transplantations to ulnar defects or to the gluteal muscles of rabbits were performed. The specimens were studied by routine histological methods, as well as by stains for collagen, alkaline phosphatase, and phosphates.

Although homogenous bone was usually well incorporated, best results were obtained with autogenous iliac bone. Shave grafts of tibial bone incited extensive osteoclastic and fibroplastic reactions, and were almost completely destroyed before healing of the defect occurred. The mechanism of destruction of the grafts has been discussed in the light of preliminary *in vitro* experiments involving bone digestion. Alkaline phosphatase localization and its role in osteogenesis have been briefly discussed.

Although peripheral areas of trabeculated iliac bone and of callus transplanted to muscle tissue occasionally survived, all such transplants to bone defects became necrotic, indicating that the speed of revascularization of a graft bed is probably the principal determining factor in maintaining viability of transplanted elements.

There was no evidence of direct osteogenetic stimulation by any elements of the transplanted fragments.

NOTE: The author wishes to express his thanks to Dr. Robert K. Lippmann, Chief of Orthopaedic Surgery, Mount Sinai Hospital, and to Dr. Paul Klemperer, Director of the Department of Pathology, Mount Sinai Hospital. Gratitude is also expressed to Mrs. Sarah Spector for her technical assistance.

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SURGERY OF THE RHEUMATIC HAND*

BY STERLING BUNNELL, M.D., SAN FRANCISCO, CALIFORNIA

Rheumatoid arthritis, a general disease, is very crippling to hands, distorting them in many bizarre patterns and rendering them unfit for use. The deformities are not only from joint changes, which are primary, but are also determined by accompanying myositic contractures. These deformities are not only generalized but are especially from the contractures of muscles contiguous to the joints, as in the intrinsic muscles in the hand. The normal muscle balance between the long extensors, the long flexors, and the intrinsic muscles becomes an imbalance, distorting the joints.

Various types of arthritis and of collagen diseases show quite similar deformities, because they result from the same mechanism.

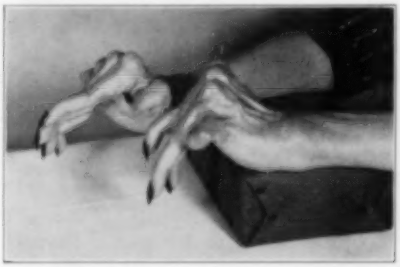

Fig. 1-A

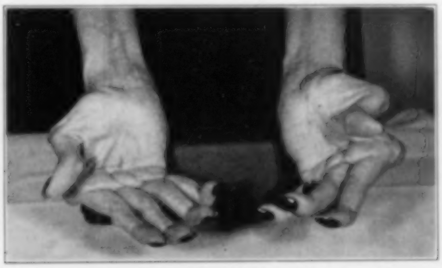

Fig. 1-B

S. F., aged fifty-eight, had a nine-year bout of rheumatoid arthritis which had terminated nine years ago. Typical deformities continued to increase. These included irreducible dislocation of the proximal finger joints and extension of the middle joints, and luxated extensor tendons with ulnar drift. The thumb showed contraction of the long abductor, short flexors, and adductors. Shortening of the metacarpals at their distal ends is needed for the fingers and through the proximal end for the thumb. Replacement of the extensor tendons over the knuckles is also needed.

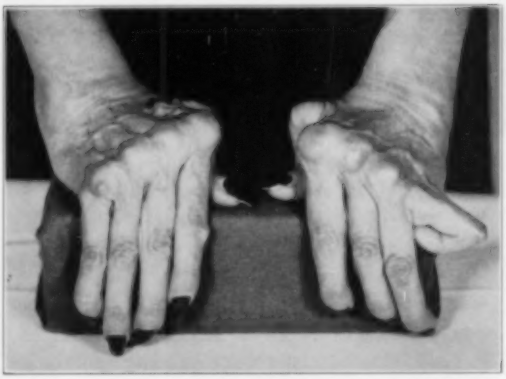

Fig. 1-C

In 1948, and later in 1953, the author drew attention to the condition of ischaemic contracture, local, in the hand, compared to Volkmann's ischaemic contracture in the forearm, showing the positions assumed and the surgical means of correction. Subsequently it was seen that the deformities of rheumatoid arthritis fit well into this picture. From ischaemic contracture, not rheumatic, the proximal finger joints draw into flexion and the distal two into extension. The thumb also, by contracture of the adductor muscles, is drawn into the palm toward the third metacarpal. This is the "intrinsic-plus" position of a hand entering a coat sleeve, as compared with the claw-hand or "intrinsic-minus" position of paralysis.

In flare-ups of the rheumatoid arthritis, the finger joints may be so distended with fluid that their ligaments become lax, and the joints are left so loose that they are an easy

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* Read at the Annual Meeting of the American Society for Surgery of the Hand, Los Angeles, California, January 28, 1955.

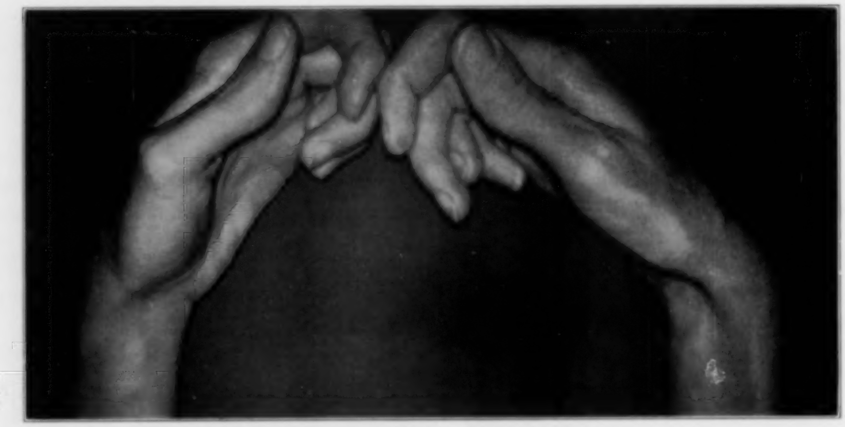

FIG. 2-A

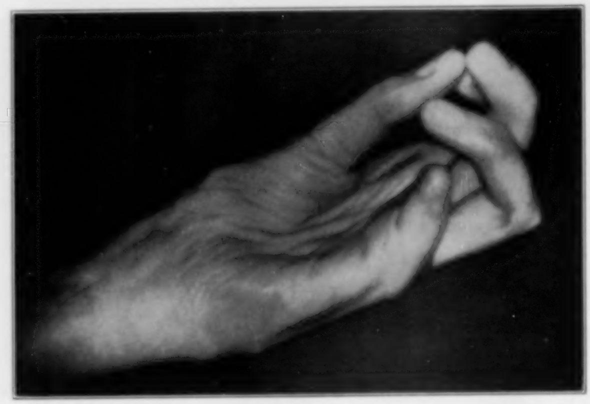

FIG. 2-B

F. S., aged thirty-one, for nine years had flare-ups of rheumatic fever, but had had none for the past seven years. This condition had been diagnosed lupus erythematosus. There were dense myositic contractures in the forearms and hands with flexed wrists.

Operation included arthrodesis of the left wrist and tenotomy of the thumb tendons. An attempt was also made to elongate the flexor tendons of the fingers, but too much fibrosis interfered.

Fig. 2-B shows the hand after operation. There was improvement in position of the thumb and the wrist and in the ability to pronate and to supinate.

prey for muscle contracture. The deformities vary according to which set of muscles predominates in their contracture. Thus, if, as occasionally happens, the long extensors are primarily involved, the metacarpophalangeal joints are pulled into hyperextension, thus overcoming the resistance of

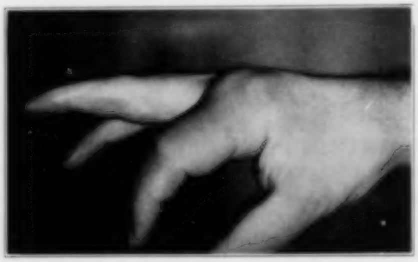

FIG. 3-A

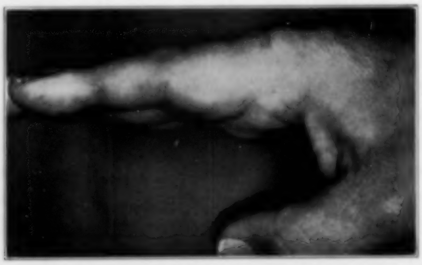

FIG. 3-B

Fig. 3-A: M.D., aged forty-three, had deformity resulting from gout. The proximal joint of the index finger was dislocated so that the patient could not extend or abduct the finger.

At operation the metacarpal of the index finger was shortened at its proximal end and the first interosseus was freed.

Fig. 3-B: The dislocation remained reduced. Patient could extend finger and could write again; and, because he could abduct his index finger, he could again wind his watch.

the intrinsic muscles. The fingers then flex in their middle joints and extend in their distal joints. By far the most usual deformity, however, is flexion of the metacarpophalangeal joints by intrinsic contracture, as these muscles are especially prone to be affected because of their close proximity to the involved joints. The middle and distal joints may thus be pulled straight by the lateral bands, or at times the middle joint may hyperextend and consequently the distal joint may flex, as is occasionally seen in ischaemic contracture.

The muscles are in spasm at first from irritation, but finally are fibrosed and shortened in fixed contracture. Microscopically the muscles, tendons, and ligaments show multiple

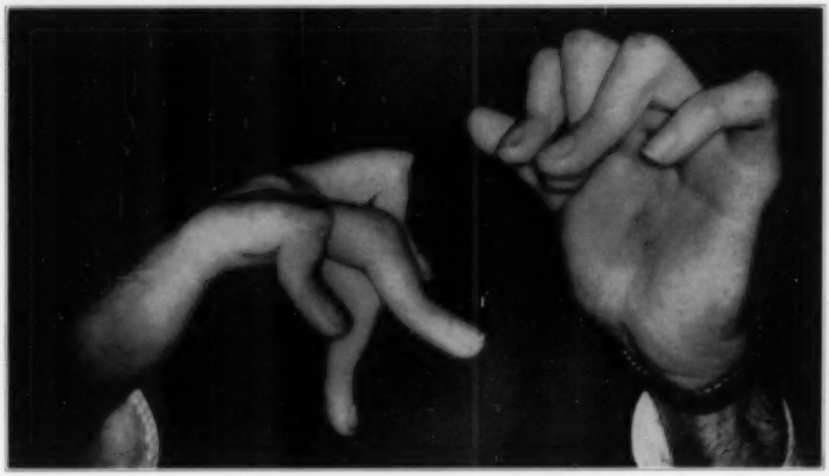

Fig. 4-A

H.J., aged twenty-six, had rheumatoid arthritis periodically over a period of ten years, beginning eighteen years ago. Most of his joints had become stiffened and both knees and elbows were ankylosed.

The fingers were deformed by contractures of the long extensors and of the interossei. The patient complained especially that he could not extend the proximal joint of the long finger of the right hand and that the middle joint of the little finger was overflexed.

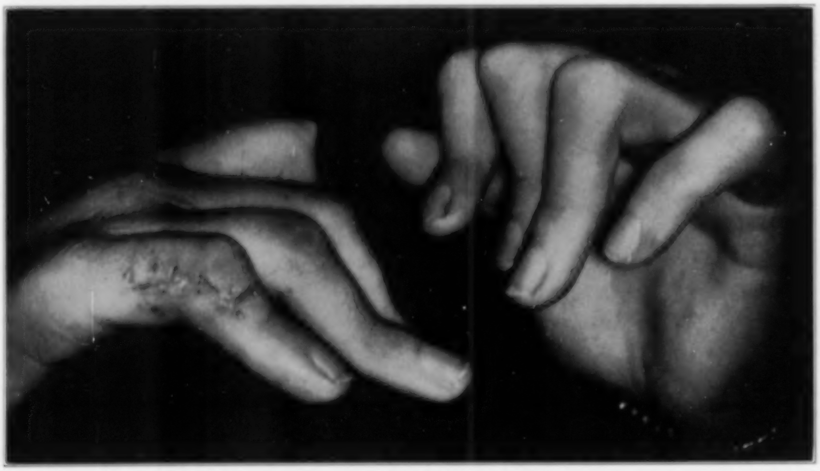

Fig. 4-B

At operation the lateral bands of the long finger were severed and the collateral and volar ligaments of the middle joint of the little finger were excised. Much improvement resulted. Later he gained 90 degrees of useful motion from an arthroplasty of one elbow.

minute foci of inflammation and later fibrotic contracture. Some ligaments, for example the middle slips of the metacarpophalangeal joints, degenerate and are replaced by granulation tissue, allowing the joint to subluxate. The joint ligaments share in the contracture as do all surrounding soft parts, but the position of deformity is largely determined by the muscle imbalance. In a flexion contracture, all tissues from skin to bone become secondarily contracted.

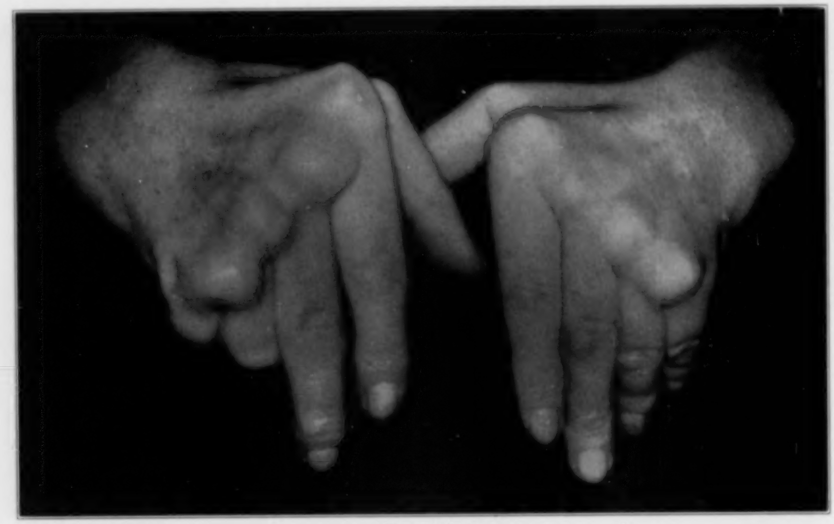

Fig. 5-A

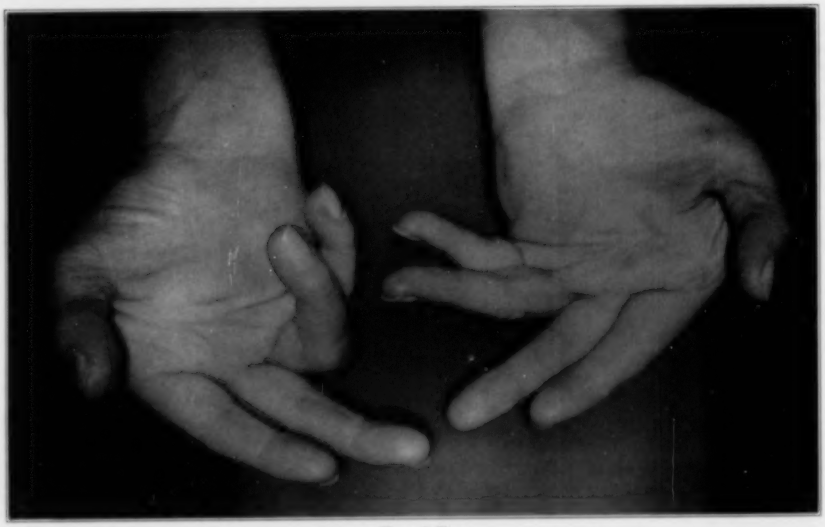

Fig. 5-B

L. O'L., aged forty-five, twenty years ago had rheumatoid arthritis of the hands and later of one foot which lasted three years. She has had no acute attacks for seventeen years, but the deformities have increased.

The two hands were similar. The proximal finger joints were irreducibly dislocated, and the extensor tendons were luxated. Hence there was an ulnar deviation of 40 degrees. She could not extend these joints. There was a typical thumb deformity. All digits showed intrinsic contracture.

At operation on the right hand, one inch of the distal end of the finger metacarpals was excised, and the phalanges were temporarily pinned to the metacarpal stumps. The extensor proprius tendons were transferred to the radial side of the index and little fingers.

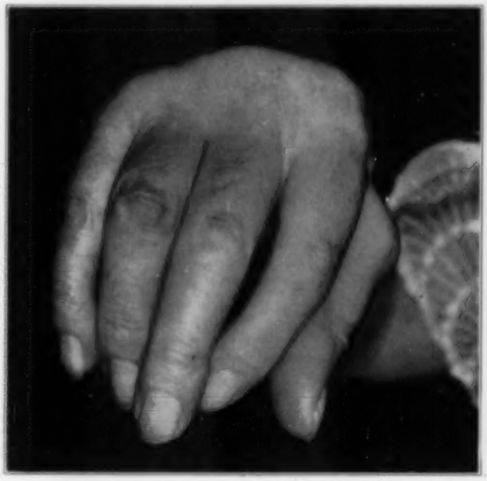

FIG. 5-C

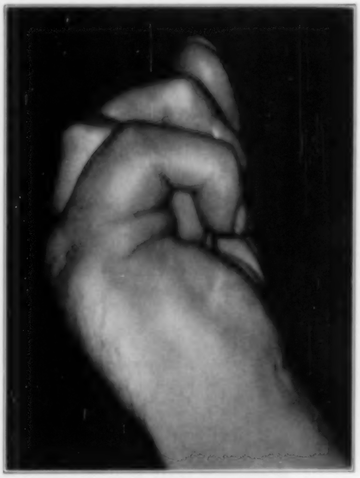

FIG. 5-D

Figs. 5-C, 5-D, and 5-E show great improvement in alignment and function of the hand. The patient can make a fist and can extend the fingers fairly well. The ulnar drift has been corrected. She grips more strongly, picks up objects better, and uses all fingers on the typewriter.

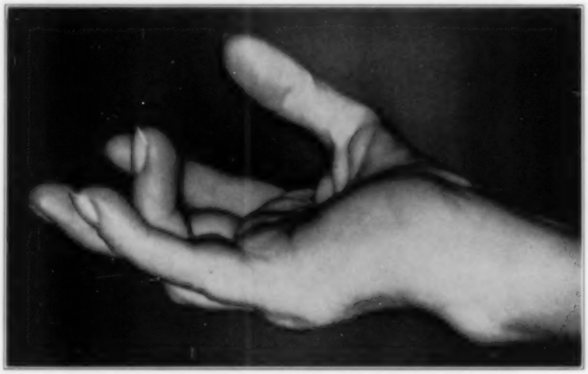

FIG. 5-E

Ulnar deviation of the fingers at the metacarpophalangeal joints is usual in rheumatoid arthritis. Normally the range of finger motion is more in ulnar than in radial deviation; so in the subsequent contracture the long extensors, increased in tension by the overflexed proximal finger joints, stretch the affected dorsal aponeurosis and luxate into the interknuckle grooves. They then cannot extend the joints, but instead flex them ulnarward.

The intrinsic muscles (interossei and lumbricales contract so strongly that they dislocate the proximal phalanges to the volar aspects of the metacarpal heads, even to the extent that they cannot be passively reduced.

The thumb, drawn by the short flexors in the thenar eminence, overflexes in the metacarpophalangeal joint with consequent pull on the long extensor which hyperextends the distal joint. In other cases, the short adductors may predominate, drawing the first toward the third metacarpal.

Early Treatment

Much can be done by mild elastic traction to maintain the position of function as

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Fig. 6-A: M.W., aged fifty, had rheumatic fever for eleven years beginning twenty-two years ago. Deformities had increased, bilaterally and symmetrically.

Figs. 6-A, 6-B, and 6-C: Proximal finger joints were dislocated but could be reduced. Extensor tendons

(*Continued on page 764*)

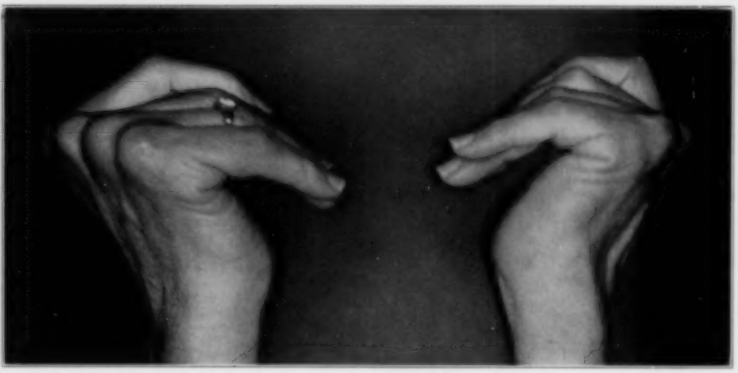

FIG. 6-A

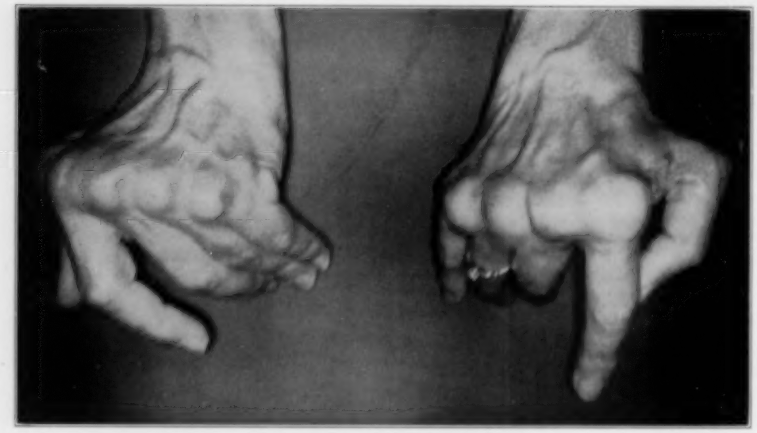

FIG. 6-B

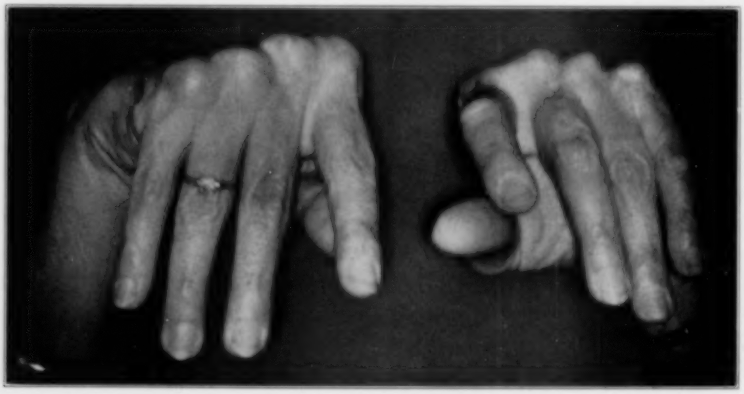

FIG. 6-C

were luxated, resulting in the ulnar deviation. The patient could not extend the proximal finger joints, but she flexed them ulnarward. The thumb showed contraction of the short flexors.

At operation on the right hand, the metacarpals of the fingers were shortened one-half inch and were temporarily pinned. The transverse fibers and lateral bands were severed so that the dislocations could be reduced. The extensor tendons were replaced over the knuckles. The short flexors and adductors of the thumb were tenotomized.

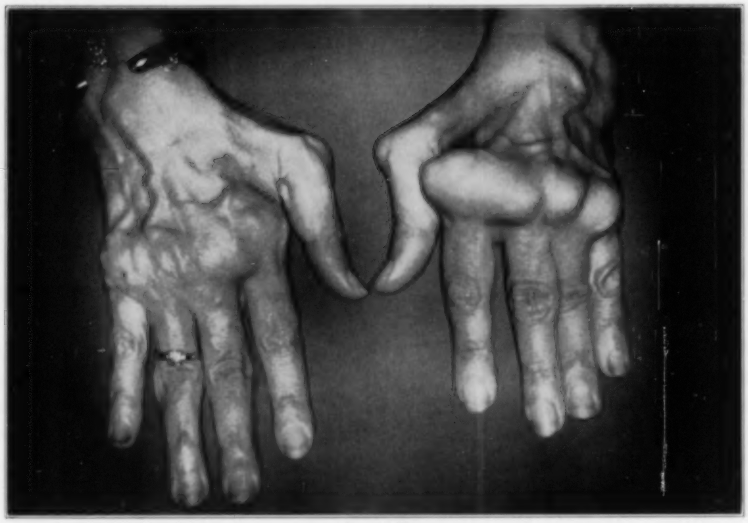

FIG. 6-D

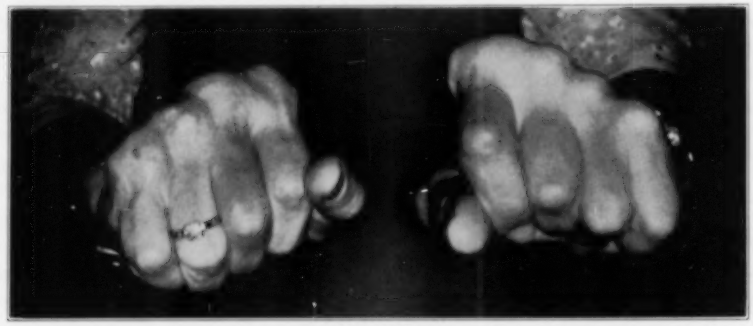

FIG. 6-E

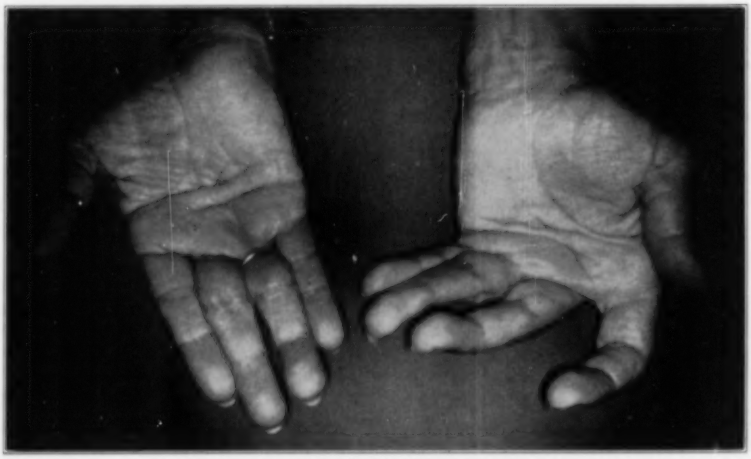

FIG. 6-F

There was great improvement in alignment and function. Proximal finger joints could be extended. The dislocations of the proximal joints and luxations of the tendons and the ulnar deviation had been corrected. The fingers could be flexed and straightened. The patient could get her hand into a glove and could do everything with the hand better than she could before.

soon as contractures commence and before they have become fixed. The reverse knuckle-bender splint is useful, as well as the spring cock-up splint. Exercise of the muscles lessens the atrophy.

Subsequent Treatment

Surgery should be used only in the "burned-out cases". About 70 per cent. of the patients with rheumatoid arthritis improve, and in many the process becomes quiescent and the bone recalcifies, but the cicatrix remains. The usual course is from three to five years, although there is the hazard of subsequent flare-ups, and in some cases the disease is progressive.

One approach is by correcting the muscle balance and relieving the tension of the muscles.

In some cases, arthrodesis to restore the position of function is indicated for the wrist, for some finger joints, and even for both joints of the thumb. Tension may be relieved by tenotomy of the lateral bands or transverse aponeurosis in the fingers; this procedure allows the metacarpophalangeal joints to extend and the distal two joints to flex. The tension of all three sets of muscles may be relieved by shortening the metacarpals. This is best done at their bases, by removing a segment of bone and pinning temporarily with Kirschner wires. Whenever the dislocations of the metacarpophalangeal joints can be reduced passively, this is the operation of choice. If, however, these dislocations, whether they are dorsal or volar, cannot be reduced, it is necessary to excise the metacarpal heads, performing arthroplasties. The new joints should be pinned in alignment until enough fibrous tissue contracts around them to give some stability.

Thumb deformities are helped greatly by shortening the metacarpal at the base. Tenotomies of the short flexors or adductors have not given sufficient relief. For flexion contracture of the thumb web, the web should be cut across from the bases of the metacarpals behind to those in front. Then, by dissecting and removing the fascia and fibrotic adductors, the cleft can be spread open and so fixed temporarily by two crossed Kirschner wires through the first two metacarpals. If no musculature is left, a wedge bone block is used to hold the thumb in opposition. The cleft is then covered by a pedicle skin graft from the abdomen.

The ulnar drift can be relieved by the following procedure: If the metacarpals are shortened at their bases, the metacarpophalangeal joints can be extended by tenotomy of the lateral bands and of the transverse aponeurosis. Each extensor tendon should be lifted free from the dorsal aponeurosis and transferred and sutured into a slit in the dorsal aponeurosis on the radial side of the knuckle. If arthroplasties are done, a similar procedure may be used; a tendon transfer of the extensor indicis proprius to the radial side of the lateral band of the index finger and a similar transfer for the little finger will furnish abduction to these fingers.

By these procedures in a small series of patients, considerable function was restored to these pitifully crippled hands, improving but not curing them.

DISCUSSION

Dr. A. Steindler, Iowa City, Iowa: It is not easy to discuss a paper by such a master of the subject as Dr. Bunnell except in the spirit of complete and unconditional approbation. As for his operative technique, he is an acknowledged perfectionist; as to his operative planning, I have always found it based on sound anatomical and mechanical grounds, and his ideas presented today are no exception.

The two principal arthritic deformities of the hand and fingers are the claw-hand and the pill-roller hand.

The former represents a muscle imbalance in favor of the long finger extensors, an overthrow of the three-cornered equilibrium of the long extensors, the long flexors, and the intrinsics, caused by weakness of the latter. This imbalance by passive insufficiency of the flexors leads automatically to positions of flexion in the interphalangeal joints.

The pill-roller hand with flexed metacarpophalangeal and hyperextended interphalangeal joints is the

(*Continued on page 808*)

SPONDYLOLISTHESIS

A Critical Review of a Consecutive Series of Cases Treated by Arthrodesis *

BY DAVID M. BOSWORTH, M.D., J. WILLIAM FIELDING, M.D., LAWRENCE DEMAREST, M.D., AND MARIO BONAQUIST, M.D., NEW YORK, N.Y.

From the Orthopaedic Service of St. Luke's Hospital, New York City

The present report is of a series of 115 patients who were treated by spine fusion for spondylolisthesis in the lumbar spine. All of the operations were done or were supervised by the senior surgeon. The statistical findings, which were correlated by all of the authors, are based upon the total number of cases recorded. The operative end results which are presented, however, are based upon seventy-five patients operated on by a single technique. The length of follow-up has been from one to twelve years, the average period being four years.

MATERIAL

Among the 115 patients studied, fifty-eight were male and fifty-seven were female. Two were colored; the remainder were white. The age at onset of symptoms ranged from three years to sixty-five years, the average age being 30.4 years. When the age at onset was analyzed according to decades, it was found that symptoms began in the first decade in one patient, in the second in twelve, in the third in twenty-three, in the fourth in thirty-four, in the fifth in twenty-three, and in the sixth and later decades in twenty-two.

In this series of patients, housewives were the most common, comprising a group of thirty-one, while laborers were next with twenty-eight. Many other occupations were also represented.

Other diseases were associated with the spondylolisthesis in some of these patients. There was no relation of these conditions either to the onset or to the progression of the slipping. Carcinoma, unrelated to the spine, developed in three; diseases of the central nervous system were present in two; and severe infections, such as pyelitis, were seen in seven. In one patient, there was a history of luetic infection. Major surgery, not related to the spine, had been performed on fifty-five patients.

Three of the 115 patients had had previous spine surgery. One had been operated upon for prolapse of the intervertebral disc at the third lumbar interspace. The other two had had fusion done for spondylolisthesis at the fifth lumbar interspace. In both instances the fusion had not become solid and the symptoms had not been relieved.

FINDINGS

Level Involved

Among the 115 patients only one had a dual spondylolisthesis. This was of the fourth and fifth lumbar segments. There were thus 116 defects of the laminar arch which were located twice in the third lumbar, ten times in the fourth lumbar, and 103 times in the fifth lumbar vertebra. One was found in the first sacral segment (Fig. 1).

Forward Slipping

The amount of forward slipping of the vertebral body above on the one below was recorded as a percentage of the anterior-posterior width of the inferior surface of the displaced segment. The percentage of forward slipping found ranged from 0 to 95 per cent. (Fig. 2). The average slipping for the whole group was 19 per cent. At the third lumbar

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* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, February 3, 1955.

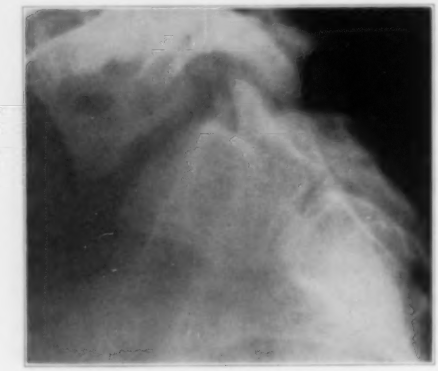

FIG. 1

Spondylolisthesis of the first sacral segment. The arch of the first sacral vertebra was a typical loose segment.

interspace it was 2 per cent.; at the fourth it was 10 per cent.; and at the fifth it was 21 per cent. Of the 103 cases of spondylolisthesis at the fifth lumbar interspace, eighty (78 per cent.) showed a slipping of less than 25 per cent. The increasing forward tilt of the upper surfaces of the inferior vertebrae at the lower interspaces is doubtless responsible for the increased slipping at the lower levels. Since the average total slipping was 19 per cent. and since the slipping of the fifth lumbar segment was less than 25 per cent. in more than three quarters of the patients, there is a strong suggestion that some specific factor tends to check the progress of the slipping at a certain point.

Relation of age to degree of slipping: No definite tendency toward greater slipping with advancing age was noted. In the first two decades, the average slipping was 25 per cent.; in the third decade it was 19 per cent.; in the fourth, 17 per cent.; in the fifth, 16 per cent.; and in the sixth and later decades it was 27 per cent.

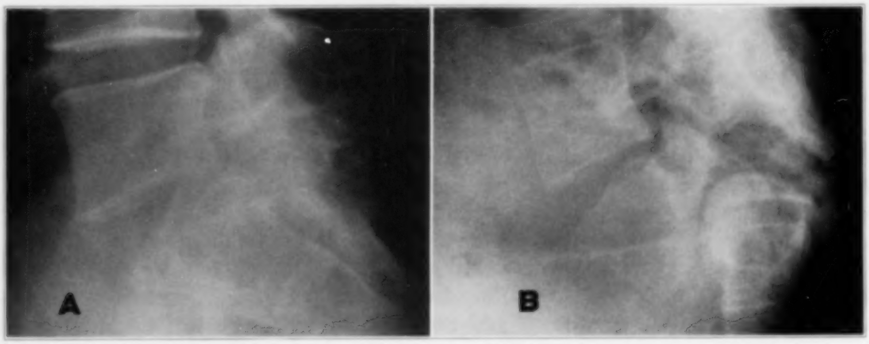

FIG. 2

Slipping varied from 0 to 95 per cent. with an average of 19.3 per cent. Note rotation of the sacrum toward a vertical position in severe spondylolisthesis (described by Harris).

Duration of symptoms and the amount of slipping: The duration of symptoms prior to surgery ranged from one day to thirty-six years, the average period being 6.5 years. The average slipping in patients with symptoms for less than one year was 20 per cent. When symptoms had been present for one to three years, it was 18 per cent.; for three to five years, 19 per cent.; for five to ten years, 20 per cent.; and for more than ten years, 21 per cent. Again it appears that, on the average, slipping will occur to about 20 per cent. of the width of the displaced vertebral body and then be checked by some mechanism.

Progressive slipping: Roentgenograms showing progressive slipping, as described by Harris (Fig. 3), were secured in two patients only. This is not interpreted to mean that such slipping does not occur, but merely that we did not obtain evidence of it in this series.

Relation of sex to the amount of slipping: The average slipping was 25 per cent. in females and 14 per cent. in males in this series. This suggests that the ligamentous, muscular, and bony supporting structures are less efficient in the female.

Influence of Trauma

Relation of onset to trauma: In fifty-six of the 115 patients the onset of symptoms was definitely related to trauma. In twenty-two instances it followed a lifting strain; in twenty a twisting injury; and in forty a fall of some severity, such as slipping on the ice. In the remaining fifty-nine patients no history of injury was obtained.

Duration of symptoms prior to surgery: The average interval between the onset of symptoms and the operation was three years after lifting strains, five years after twisting injuries, three years after falls, and eight years when no injury had occurred. Apparently, in the absence of any injury, the patients endured their symptoms for a longer period of time before submitting to surgery.

Relation of trauma to the amount of slipping: When the onset of symptoms had occurred with a lifting strain, the average slipping at the time of operation was 12 per cent.; with a twisting injury, it was 14 per cent.; and with falls, 11 per cent. When there was no history of injury, the average slipping at the time of operation was 27 per cent. Among the patients with no history of injury, there was the greatest percentage of slipping at the time of operation.

Prominence of the Fifth Lumbar Spinous Process

During this study, a new significance of this common finding in spondylolisthesis of the fifth lumbar segment became apparent. Since the amount of slipping of the third and fourth lumbar vertebrae was always minimal, not exceeding 10 per cent., and since at these upper levels the shearing stresses are greatly reduced, the present discussion does not apply to spondylolisthesis at these locations. Furthermore, in our series increased prominence of the spinous process at these levels was always minimal.

In some instances the spinous processes at the lumbosacral level were absent. These patients will not be considered here.

In this discussion the word "extrusion" will be used to refer only to backward displacement of the fifth lumbar arch with reference to the fourth.

The relationship of the fifth lamina to the sacral facets is never disturbed, except that angulation between facets may occur.

In 17 per cent. of the patients operated upon for spondylolisthesis of the fifth lumbar segment, actual extrusion of the fifth arch had occurred (Fig. 4,*E* and *F*). At operation this arch was found to be actually posterior to, that is extruded from under, the inferior border of the fourth arch.

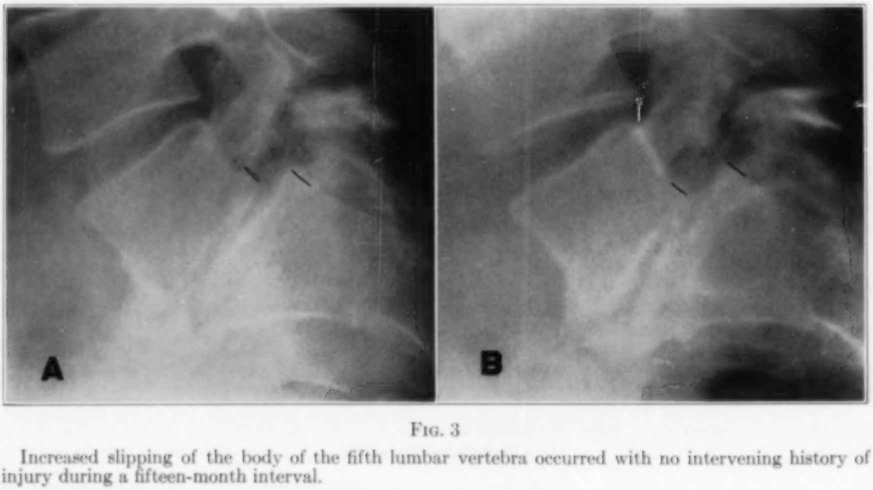

FIG. 3

Increased slipping of the body of the fifth lumbar vertebra occurred with no intervening history of injury during a fifteen-month interval.

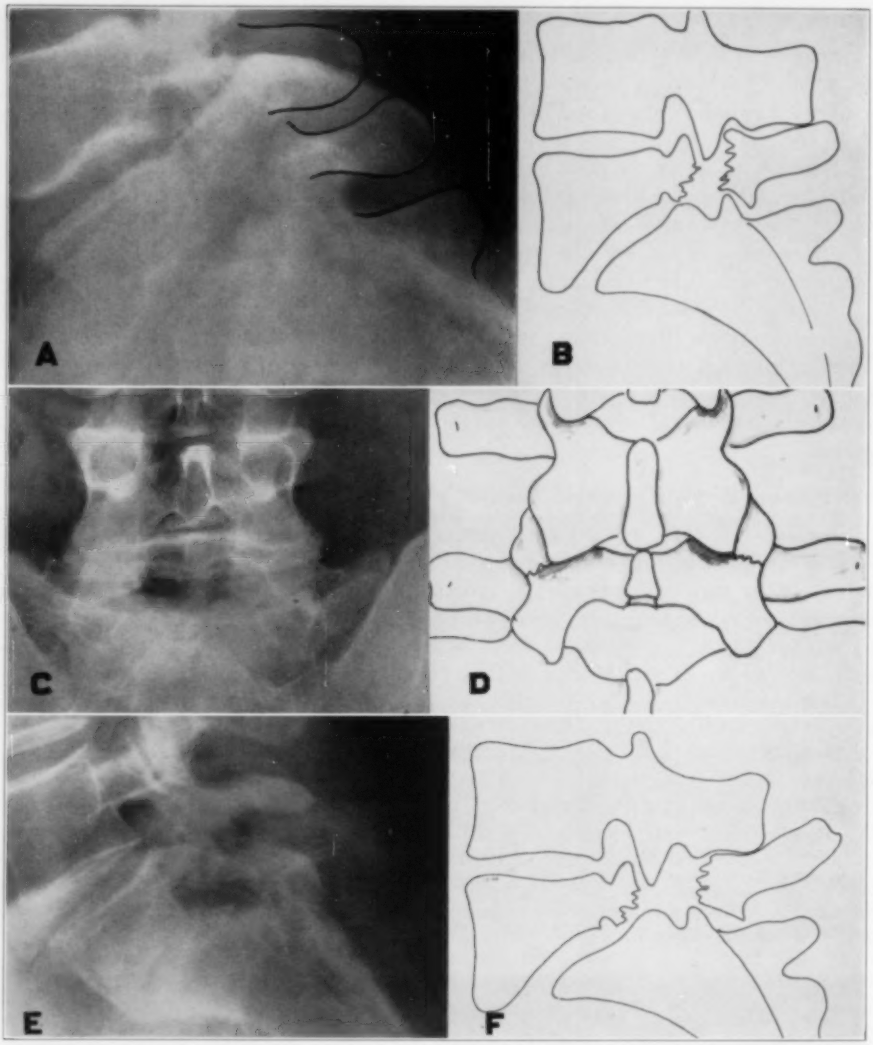

FIG. 4

A: The loose arch of the fifth lumbar segment is caught beneath the arch of the fourth lumbar vertebra. Vertical narrowing of the spinous process makes it appear longer than it actually is.

B: Diagram shows the relationship of the arch and spinous process of the fifth lumbar vertebra caught beneath the posterior elements of the fourth lumbar vertebra. Note the cephalad rotation of the spinous process of the fifth lumbar vertebra. The facets between the fifth lumbar and the first sacral vertebrae maintain the posterior placement of the arch of the fifth lumbar vertebra. Cephalad rotation has been stopped by the impingement of the upper border of the spinous process of the fifth lumbar vertebra against the lower border of that of the fourth lumbar vertebra.

C: The loose arch of the displaced fifth lumbar vertebra is caught beneath the arch of the fourth lumbar vertebra.

D: Drawing indicates the situation existing in *C*. The retained arch of the fifth lumbar vertebra acts as a supporting structure and tends to prevent further slipping.

E: The arch and spinous process of the displaced fifth lumbar vertebra has escaped from beneath the border of the fourth lumbar vertebra and protrudes posteriorly in relation to it. The arch of the fifth lumbar vertebra maintains contact with the first sacral through its facets.

F: Drawing illustrates the situation existing in *E*. The arch and spinous process of the fifth lumbar vertebra have escaped from under the border of the arch of the fourth lumbar vertebra. The facets

(*Continued on page 771*)

(*Continued from page 770*)

between the fifth lumbar and the first sacral vertebrae remain in contact. Cephalad rotation of the spinous process of the fifth lumbar vertebra and angulation of the facets between the fifth lumbar and the first sacral vertebrae have occurred. Traumatic changes in the articular surfaces of these facets have been noted.

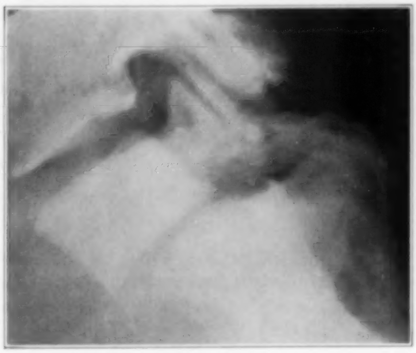

FIG. 5

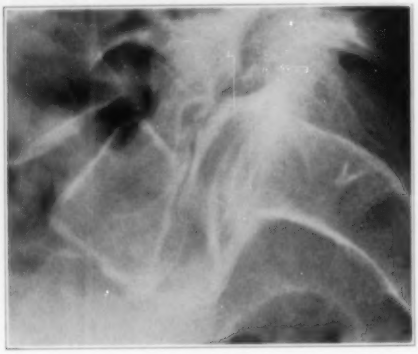

FIG. 6

Fig. 5: The posterior arch of this fifth lumbar vertebra was found to have solid bony continuity through the expected defect area. It had been impossible to determine the existence of this bony bridge preoperatively by roentgenogram. Posterior protrusion of the spinous process of the fifth lumbar vertebra was present. Specimens have shown ossified islands in the fibrocartilage from the defect at the pars interarticularis. The question arises as to whether ossification of this fibrocartilage can eventually become complete and solidly bridge the defect.

Fig. 6: Stress lines in the sacrum and ilium where they cross the upper border of the first sacral vertebra can give an appearance of osseous development at the anterior border of the sacrum, produced in an attempt to support the involved segment. No true osseous development of the upper border of the sacrum was seen in our series. Productive calcific and hypertrophic changes were noted but were always inadequate to afford support.

In 82 per cent. of the patients with fifth lumbar spondylolisthesis, the extrusion of the fifth arch is only apparent, the prominence of the spinous process being due to rotation of the arch. In these instances the upper border of the arch and the base of the spinous process of the fifth segment are caught beneath the inferior border of the lamina and spinous process of the vertebra above (Fig. 4,*A* and *B*). At the same time the inferior articular facets of the fifth arch remain in contact with the articular processes of the first sacral segment. As the fourth lumbar arch is drawn forward by the slipping of the fifth lumbar body, it therefore produces forward rotation of the fifth arch, which in turn causes the fifth spinous process to tip cephalad and to project to a moderate degree beyond the spinous process of the fourth and to a considerable extent beyond its original position. It is then prominent both by roentgenogram and to palpation. In this instance, prominence is the result of rotation and not of actual extrusion.

The rotation of the fifth arch is checked when its spinous process impinges on that of the fourth. When this occurs, further forward slipping is also stopped unless the arch of the fourth lumbar segment escapes above or slides forward over that of the fifth. In this event an actual extrusion occurs and further slipping may result. Hence the stability of the fourth lumbar arch and of the spine above this level may depend upon the fifth lumbar arch being wedged between its inferior margin above and the sacral facets below (Fig. 4, *C* and *D*).

The interposed fifth arch, therefore, acts as a lever. Its removal may be essential for theoretical purposes, such as decompressing the dural sac and nerve roots, the implantation of an adequate distraction graft, and gaining contact between the graft and the residual fifth lumbar pedicles. However, its removal does decrease the stability of the spine at this level, and restoration of support by a spine fusion is essential as will be emphasized in the discussion of the progression of slipping postoperatively.

There is considerable evidence to indicate that retention of the arch of the fifth lumbar

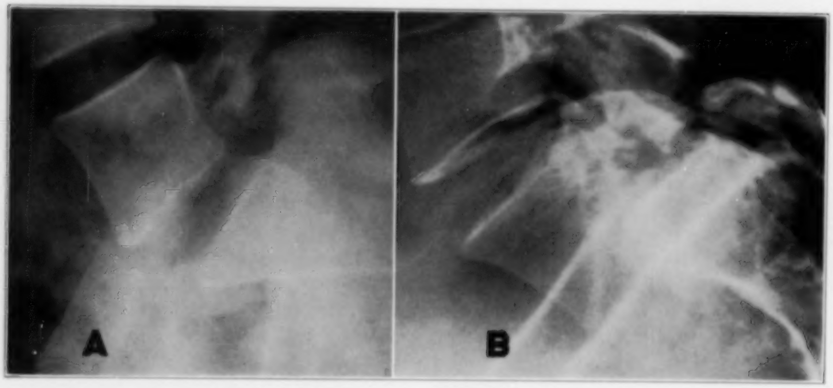

FIG. 7

The amount of wedging of the vertebral body corresponded with the amount of slipping.

vertebra is a definite factor in the stability of the spine with spondylolisthesis at the lumbosacral interspace, namely:

1. The average slipping does not exceed 20 per cent.;

2. When the amount of slipping was correlated with the degree of rotation or extrusion of the fifth arch, it was found that, when slipping of more than 20 per cent. had occurred, the arch of the fourth had as a rule escaped over the upper edge of the lamina of the fifth lumbar vertebra;

3. The average slipping remained approximately the same in all age groups;

4. The average slipping was practically constant, regardless of the duration of symptoms prior to operation;

5. In the eleven patients in whom the arch was left *in situ* at operation, no further slipping occurred postoperatively; while in nineteen of the sixty-four patients in whom the arch was removed and spine fusion was performed, some progression of the slipping occurred;

6. At operation, the loose laminar arch of the fifth lumbar vertebra could be detached from the sacrum below with ease, but its extraction from under the edge of the laminar arch of the fourth was difficult.

Arch "extrusion" versus rotation: The prominence of the spinous process of the fifth lumbar vertebra, resulting either from rotation or from extrusion of the arch, was recorded as the percentage of the length of the fifth process which projected beyond that of the fourth. This varied from 0 to 70 per cent., the average being 16 per cent. In the roentgenograms, the spinous process of the fifth lumbar vertebra often appeared to be abnormally long, due to its decreased vertical height. This is an almost universal finding in spondylolisthesis at this level. Because of this illusion of increased length, there was often some apparent, but not actual, increase of the protrusion of the fifth spinous process. When the prominence was marked — that is, 25 to 70 per cent. — some actual extrusion was usually present in addition to rotation. When true extrusion had occurred, the cephalad rotation of the spinous process of the fifth lumbar vertebra was still maintained apparently by the pull of the soft-tissue attachments. When the spondylolisthesis is of an advanced degree, the supporting mechanism between the spinous processes and the laminar arches of the fourth and fifth lumbar vertebrae is usually disrupted. However, in some instances, even with severe forward slipping of the fifth vertebral body, rotation of the sacrum, combined with wedging of the fifth lumbar body, seemed to prevent a correspondingly great displacement of the posterior elements.

Variations in the Laminar Arch

Variations in the defect in the arch: In six patients in this series there was bony continuity across the portion of the arch where the defect is usually found. One patient with spina bifida had intact bone across the pars interarticularis on one side with a typical fibrous-tissue defect on the other. Two had osteo-arthritis of the facet area, and for this reason appeared to have spondylolisthesis at the fourth and fifth lumbar interspaces, respectively. In the first of these two, it was not recognized preoperatively that the arch was intact, but in the second it was apparent prior to operation that there was no defect in the arch. Three patients had such typical findings, both clinically and roentgenographically, that the bony continuity found at operation was not suspected preoperatively (Fig. 5). These cases are to be distinguished from the pseudospondylolisthesis described by Norcross [12,13,14], Macnab, and others. In all of these patients, a routine fusion was done without removing the arch or visualizing the pedicles and pars interarticularis. Hence these cases furnish no evidence one way or another as to whether ossification had occurred across a previous defect. However, there is a suggestion from the microscopic findings in another patient in whom the arch had been removed that ossification may develop across the defect.

Spina bifida: In this series, thirty patients had spina bifida. In nine, it involved the fifth lumbar arch and was occult. Two of these had, in addition, complete sacral spina bifida. Twenty-one patients had spina bifida involving more or less of the sacrum. In five of these latter patients, there was complete sacral spina bifida. In all thirty patients the average slipping was 20 per cent. compared with 25 per cent. in those in whom no spina bifida was present. Seventeen spines with spina bifida were fused by means of H-grafts of autogenous iliac bone reinforced with iliac strips. In sixteen of these (94 per cent.), the fusion became solid; in one (6 per cent.), it was unsuccessful.

Underdevelopment of the arch: This was found in forty-five patients in this series. It was mild in nineteen of them, moderate in twenty-three, and marked in three. The defect was found only in the fifth lumbar vertebra; it did not appear to influence the amount of slipping.

Unilateral deformation of the arch: This was found in ten patients (Fig. 8). It was mild in one, moderate in seven, and severe in two. Considerable slipping was generally associated with this defect.

Changes in the Intervertebral Spaces

Herniation of the intervertebral disc: In one patient with spondylolisthesis at the fifth lumbar interspace, a typical disc prolapse at the third lumbar interspace had been removed at a previous operation. Another patient sustained a laceration of the third lumbar disc following solid spine fusion from the fourth lumbar vertebra to the sacrum for spondylolisthesis at the lumbosacral interspace. In sixty-one patients, the arch was removed and the disc was explored at the time of the operative repair of the spondylolisthesis. Only one of these patients was found to have a true herniated disc at the fourth lumbar interspace with multiple small fragments protruding as a mass. In these patients, the annulus was not incised in order to explore for degeneration or fragmentation of the disc, if the anterior wall of the canal was smooth.

Narrowing of the interspaces above and below the vertebral defect: In seven patients, the disc space immediately above the level of the spondylolisthesis was narrowed (Fig. 17, *B*). This narrowing was 25 per cent. in two, 50 per cent. in three, and 75 per cent. in two. In fifty patients, the interspace at which the displacement occurred was narrowed (Fig. 3). This was 25 per cent. in nine, 50 per cent. in nineteen, 75 per cent. in fifteen, and 95 per cent. in nine. Occasionally both the fourth and fifth lumbar interspaces were narrowed. In fifty-eight patients no change in the width of either interspace was apparent on the roentgenogram. When the amount of slipping of the vertebral body was correlated with the narrowing of the interspace at the level of displacement, it was found that the

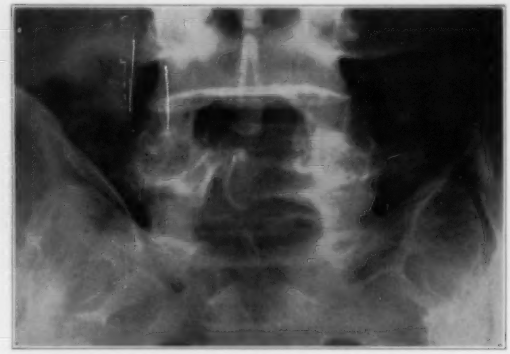

FIG. 8

Deformation of the arch can be seen on the left; this was not noted so frequently as was underdevelopment of the arch Both are shown here. The association of spina bifida is discussed in the text.

average slipping was 9 per cent. when there was no narrowing and 28 per cent. when narrowing had occurred. It would seem, therefore, that an intact disc is a factor in decreasing or preventing slipping.

Sclerosis of abutting margins and bony proliferation anteriorly: Of the fifty-one patients without narrowing of the interspace at the level of displacement only one showed sclerosis of the adjacent vertebral plates and bony proliferation anteriorly. In contrast to this, in those interspaces where narrowing had occurred, sclerotic changes were routinely present. The amount of sclerosis was directly related to the amount of narrowing. It seemed to be the result of this narrowing and not of the spondylolisthesis.

One observation of some importance is that stress lines in the lateral masses of the sacrum or in the ilium may be superimposed on the superior and anterior borders of the body of the first sacral vertebra in the lateral roentgenogram, giving the appearance of bony overgrowth of this portion of the first sacral segment. It would seem that in the past it has been assumed that the upper border of the sacrum grows forward to form a support for the anteriorly displaced fifth lumbar vertebra. In this series no such growth was found except for hypertrophic osteo-arthritic changes which were entirely inadequate as supporting structures. These changes were found primarily at the fifth lumbar interspace. They seemed to be the result of stress on ligamentous structures. They were found after the slipping of the body had occurred and not in advance of this.

Changes in the Displaced Vertebral Body

Variations in the vertical diameter of the displaced vertebral body: The vertical length of the anterior margin of the displaced vertebra was diminished as compared with the vertebra above it in sixteen patients. This amounted to 10 per cent. in nine, to 20 per cent. in six, and to 40 per cent. in one. It occurred in the fifth lumbar vertebra in all but two patients. In these two it occurred in the fourth lumbar vertebra and amounted to approximately 10 per cent. The narrowing was not necessarily related to the amount of slipping; for instance, one patient with a slipping of 95 per cent. of the fifth lumbar vertebra had almost no change in the vertical measurement of the body, while another with a slipping of 50 per cent. had a decrease in height of 40 per cent.

Variations in the anterior-posterior diameter of the displaced segment: The anterior-posterior diameter of the displaced vertebral body, when compared with that of the vertebra above, was decreased approximately 5 per cent. in four patients and 10 per cent. in three. In two patients, it was increased approximately 5 per cent. There was no apparent relationship of this to the amount of slipping; for instance, in one patient with a mild decrease in the anterior-posterior diameter, the slipping amounted to 40 per cent., while in another with a moderate decrease there was only a 5 per cent. slipping. However, the changes in the anterior-posterior measurement did accompany narrowing of an adjacent disc, for all nine patients with this change were included in the fifty-eight patients with narrowing of an interspace. Apparently changes in the anterior-posterior diameter do not occur unless there is an associated narrowing of the interspace, but the narrowing of the interspace is not the cause of the change. These changes in both the anterior-posterior and the vertical diameters were limited almost exclusively to the fifth lumbar vertebra. They were not related to atrophy or to other changes in the arch of the slipped vertebra, nor was there any correlation with age, sex, or duration of symptoms.

Wedging of the vertebral body: Wedging of the vertebral body due to diminution of the vertical diameter posteriorly occurred in fifty-four patients. It amounted to approximately 25 per cent. in twenty-two; 50 per cent. in twenty-two; and 75 per cent. or more in ten. The amount of wedging was ordinarily directly related to the amount of slipping (Fig. 7). With no wedging, the average slipping was 9.5 per cent.; with 25 per cent. wedging, it was 21.0 per cent.; with 50 per cent. wedging, it was 28 per cent.; and with 75 per cent. wedging, it was 34 per cent. However, there were instances when there was a gross lack of correlation. For instance, in one patient with slipping of 5 per cent., wedging of the body amounting to 50 per cent. was found. In general there was a definite tendency for the amount of wedging to correspond with the amount of slipping.

Intact bony arches were found in two patients with 50 per cent. wedging of the slipped vertebra and with forward slipping amounting to 10 per cent. and 50 per cent., respectively. The findings in these patients would seem to lend further support to the previously expressed idea that bony continuity of the pedicles with the laminae does not preclude the possibility of a pre-existing spondylolisthesis.

Unilateral deformation of the vertebral body: In one patient, unilateral deformation of the vertebral body was found in association with deformation of the arch. It was of moderate degree and was accompanied by only 5 per cent. slipping of the body. No hemivertebra was found in this series.

Functional Derangements of the Spine Associated with Spondylolisthesis

Mobility of interspaces above and at the level of the defect: This was determined by lateral roentgenograms made with the patient in flexion and extension. When narrowing was present, motion was usually limited. Abnormally increased motion may result when the ligamentous structures are relaxed and the intervertebral disc is apparently intact (Fig. 9). There were fifty patients who had narrowing of the interspace at the level of the defect. Of these, forty-two had restriction of motion. Narrowing of the interspace above the site of the spondylolisthesis was found in seven patients, all of whom showed limitation of motion. It is apparent that narrowing of the interspace, sclerosis of the abutting vertebral plates, and bony proliferation anteriorly are all interrelated and are also associated with

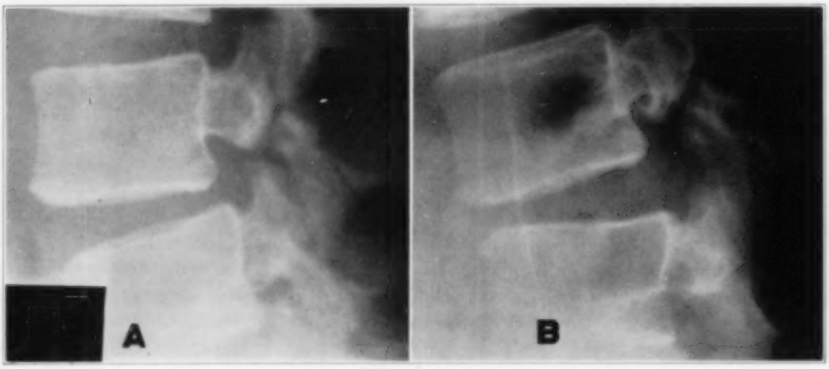

Fig. 9

Abnormality of the motion of the affected segment was noted with relaxation of the ligamentous structures when the disc interspace remained relatively normal.

loss of mobility at this interspace. It seems probable that the symptoms from spondylolisthesis, such as protection and muscle spasm, are related to these secondary changes which accompany degeneration of the disc. In our opinion, symptoms also arise from malalignment of the articular facets, from actual impingement of the abutting laminar arches and spinous processes, and from ligamentous strain. These latter factors were present not only in the fifty-seven patients exhibiting degenerative changes, but also to some extent in the remaining fifty-eight in whom no narrowing or other disc changes were seen by roentgenogram. Since cartilage has no nerve supply, the degeneration of the disc *per se* cannot be a cause of the pain in spondylolisthesis. In our series, the rare occurrence of a posterior disc prolapse, combined with our inability to find hypertrophied masses of fibrous tissue at the defect in the pars interarticularis, suggests that the pain of spondylolisthesis is not due to nerve-root compression.

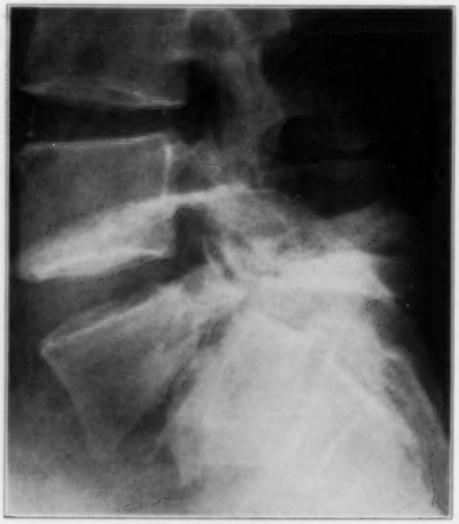

Fig. 10

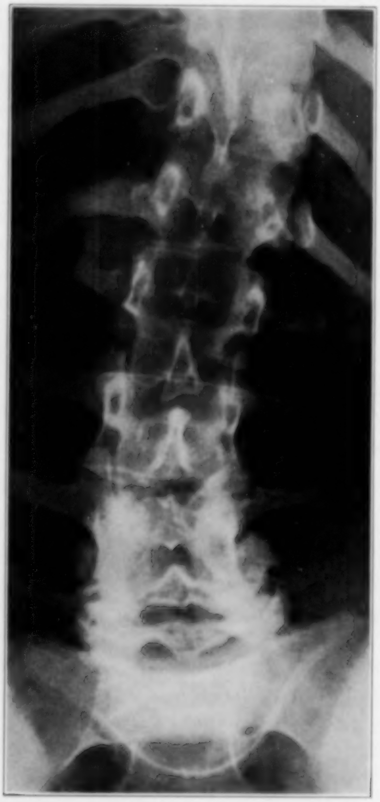

Fig. 11

Fig. 10: Increased lumbar lordosis was noted in half of the patients. This roentgenogram, however, showed that increased lumbar lordosis is not brought about by forward slipping if the slipped vertebral body is sufficiently wedged.

Fig. 11: Twenty-six of the 115 patients had some degree of scoliosis. The frequency of the occurrence of scoliosis was too great to be coincidental.

Lumbar lordosis: By this is meant lordosis of the lumbar spine exclusive of the lumbosacral joint. Less than half of the patients showed any increase of the lumbar lordosis by roentgenogram. The amount of lordosis did not appear to be related to the degree of spondylolisthesis. For instance, one patient with slipping of 25 per cent. showed a marked increase in lordosis of the lumbar spine, while another with the same amount of slipping showed only a slight increase. However, the amount of lordosis does seem to be related to the amount of wedging of the body of the involved vertebra, on the one hand, and to the extent of degenerative changes in the intervertebral disc on the other hand, as shown by narrowing, sclerosis, and productive changes. Fifty-six patients had some increase of the lumbar lordosis. In forty-nine of these, there were associated degenerative changes in the intervertebral discs as compared with seven patients who exhibited an increased lordosis in the absence of disc changes. Not infrequently, marked forward slipping without definite associated disc changes was found in patients who showed no increase of lumbar lordosis. In forty-five of the fifty-six patients with increased lumbar lordosis, there was some associated wedging of the body of the involved vertebra. However, this was not sufficient to compensate for or to prevent the development of the abnormal lordosis. It is worthy of note that the roentgenographic and clinical findings with respect to increase of the lumbar lordosis did not always correspond. The roentgenograms revealed this in many patients in whom it was not apparent clinically. The severity of the symptoms and disability did not correspond with the degree of lordosis. It would seem that increased lordosis is not a protective mechanism. Similarly it is not necessarily the result of the forward slipping, for, if the displaced vertebral body is sufficiently wedged, its superior surface remains roughly horizontal, and increased lordosis does not occur.

Associated dorsal kyphosis: Only eight patients in this series showed this deformity. It was generally mild and appeared to be an incidental finding.

Associated scoliosis: There seemed to be a definite association between scoliosis in the lumbar region and spondylolisthesis. Twenty-six of the 115 patients in this series had some scoliosis. In fifteen it was mild, in nine it was moderate, and in two it was severe. No relationship was apparent between the amount of slipping and the severity of the scoliosis.

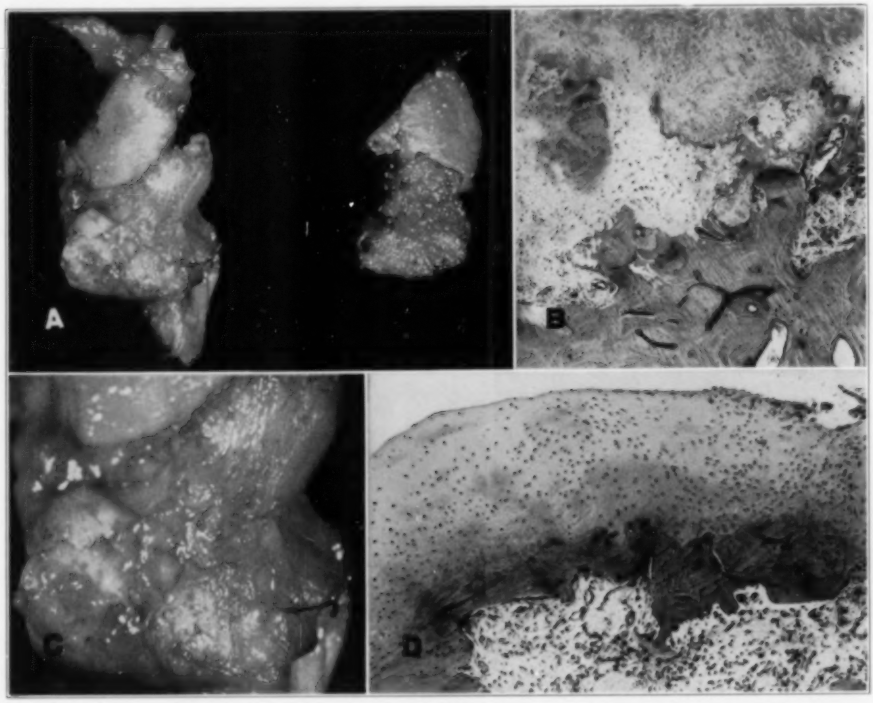

Fig. 12

A: The ventral surfaces of the left and right pedicles of a fifth lumbar vertebra in a case of spondylolisthesis. The defect area, below on the right, shows fibrous attachment; that on the left a pseudo joint. Above are the inferior facets of the fifth lumbar vertebra which show degenerative changes.

B: Photomicrograph of section taken from the defect shown on the right in *A* shows complete fibrocartilaginous attachment.

C: Enlargement of the left pedicle defect shown in *A*. There is a pseudo joint at the defect of the pars interarticularis.

D: Photomicrograph shows fibrocartilage to be present in the defect of the pars interarticularis shown in *C*. Note the free margin of the cartilage at the pseudo joint.

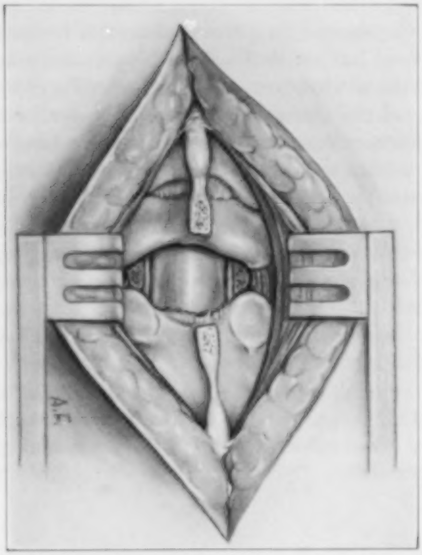

Fig. 13-A

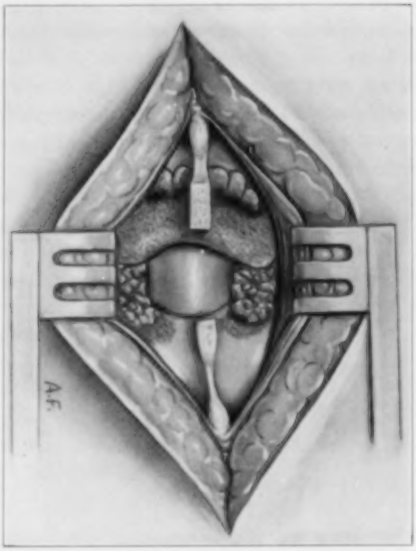

Fig. 13-B

Fig. 13-A: Removal of the arch of the affected segment was first done by us in 1941. Removal of the arch facilitates implantation of the H-graft and allows direct contact of the strip graft with the arch of the fourth lumbar vertebra and the superior articular facets of the first sacral vertebra.

Fig. 13-B: Denudation of the pedicle stumps to allow contact with graft material was begun in 1942. Chip grafts in contact with the denuded pedicles have been shown to solidly unite the affected segment with the rest of the fusion. Denudation of the posterior elements above and below the affected segment is shown.

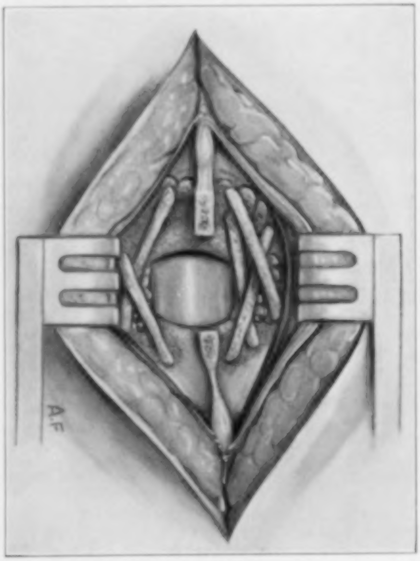

Fig. 13-C

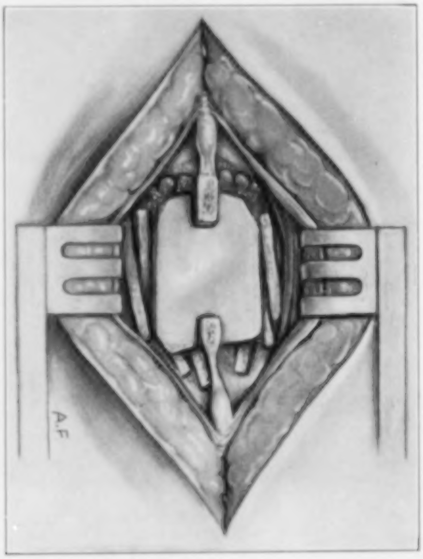

Fig. 13-D

Fig. 13-C: Cancellous iliac-strip grafts have been placed across the denuded laminae.

Fig. 13-D: The H-graft has been placed dorsally to the strip and chip grafts with the patient in a flexed position. It is solidly held in place with the patient extended, as shown. (Figs. 13-A, 13-B, 13-C, and 13-D are reproduced from "Technique of Spine Fusion" by David M. Bosworth, *Instructional Course Lectures*, The American Academy of Orthopaedic Surgeons, 1952, Vol. IX, page 47. Ann Arbor, J. W. Edwards, 1952.)

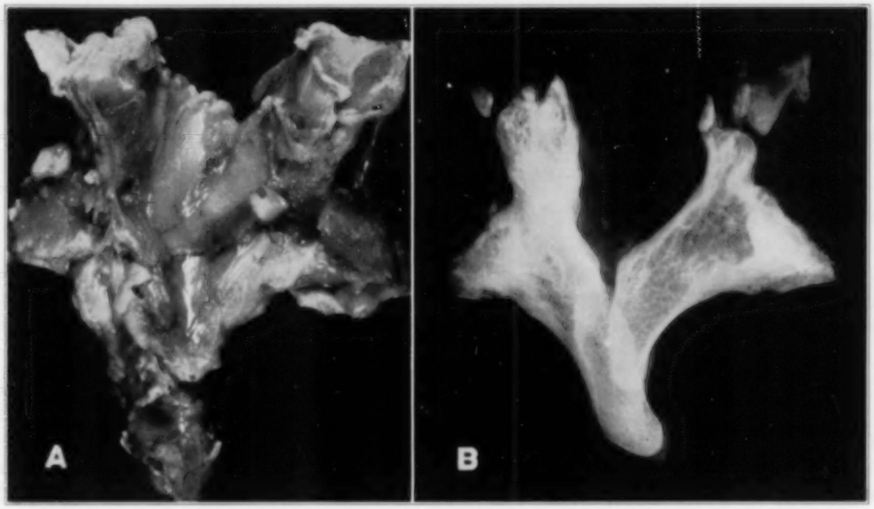

Fig. 14-A

Fig. 14-B

Fig. 14-A: Ventral surface of the specimen removed from an affected segment. Ossified areas in the fibrocartilaginous remnants from the defect of the pars interarticularis appear at the top.

Fig. 14-B: Roentgenogram of the specimen reveals the ossified islands in the fibrocartilaginous matrix in the defect in the pars interarticularis.

Fig. 14-C: Photomicrograph showing the bone islands and the fibrocartilaginous matrix within the defect of the pars interarticularis.

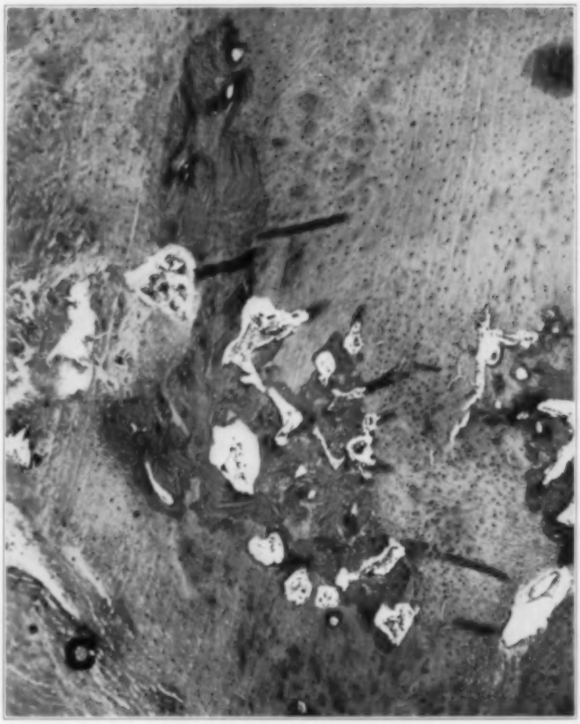

Fig. 14-C

Clinical Findings

The preoperative physical examination of the 115 patients in this series showed definite decreased mobility in forty-nine, a palpable notch in forty-six, tenderness in forty-five, a positive Lasègue sign in thirty-nine, protection of the back in twenty-five, spasm of the spinal musculature in twenty-four, increased lordosis in twenty-three, hypotonicity of the muscles of the buttocks and thighs in twenty-three, a shift of the trunk in twenty-two, measurable atrophy of the lower extremity in fifteen, diminution of the ankle jerk in fourteen and of the knee jerk in eleven, hypo-aesthesia to pin prick in a distribution corresponding to the lower lumbar dermatomes in eleven, and weakness of dorsiflexion of the foot and great toe in four. None of the patients showed clonus or the Babinski sign. There were thirteen who exhibited none of these findings.

The positive findings in this series of patients were scattered throughout the group. Rarely did they occur in combination in one patient in such a fashion as to present the picture of extradural nerve-root pressure, as from a posterior herniation of an intervertebral disc. Most of the findings in the lower extremities were mild or minimal. With the exception of one patient who had a neuropsychiatric consultation, none had neurological or psychiatric examinations.

Characteristically a patient with spondylolisthesis gives a history which leads one to suspect herniation of an intervertebral disc, yet the physical examination shows minimal or no findings consistent with this diagnosis. So common is this clinical picture that the diagnosis can often be suspected even before the roentgenograms are seen.

TREATMENT

Selection of cases for final study: The present study was limited to patients operated upon for spondylolisthesis during the period 1944 to 1953 inclusive.

In previous studies we have presented our results with other operative techniques including the Hibbs-type fusion, with and without reinforcing iliac strips, and tibial H-grafts with and without additional iliac strips. These patients are excluded from the present study.

During the period under consideration spine fusions were performed on eleven patients without an H-graft. Iliac grafts in the form of strips were placed on each side in contact with the laminae. This technique was necessary because of associated spina bifida in eight patients and because of other mechanical situations, such as the absence of a spinous process of the first sacral in three patients. After nine of these operations the fusion became solid; one resulted in a pseudarthrosis throughout the extent of the fusion area. One patient died of diabetes and related complications before results of the operation could be determined. Since this report concerns a standard technique, these eleven patients were deleted from this study except for this brief summary.

Group for final study: There remain seventy-five consecutive patients on whom spine fusion for spondylolisthesis was performed by a single technique. These were studied with regard to operative findings, and as to final results.

Most of these patients had had intensive treatment over long periods of time prior to surgery. This had consisted in rest, decrease in activity, and the wearing of supporting belts and braces. Fourteen had been treated by manipulation of the spine.

Operative technique: Since 1944 our routine procedure has been to implant an autogenous, cortical iliac graft of the distraction type, supplemented by strips of cancellous iliac bone placed beneath it. Since 1941 we have, as a rule, removed the fifth lumbar laminar arch. Since 1942 the bone grafts have been placed in contact with the previously denuded stumps of the pedicles of the displaced segment. The arch was removed in sixty-four instances and left *in situ* in eleven.

All wounds were closed with chromic catgut sutures in the deep layers and with silk sutures in the superficial layers. The operative time ranged from thirty-five to eighty minutes, except for five operations performed on the teaching service, when the procedure lasted one and one-half to two hours. The average operative time was sixty-nine minutes. Transfusions and intravenous infusions were administered routinely during operation.

Location of the fusion: Of the seventy-five fusions, sixty-six were from the fourth lumbar vertebra to the sacrum, six were from the third lumbar vertebra to the sacrum, two were from the third to the fifth lumbar vertebra, and one was from the second to the fourth lumbar vertebra.

Postoperative care: The period of hospitalization ranged from seventeen to forty-nine days. The average hospital stay was 24.6 days. The patients were allowed to get out of

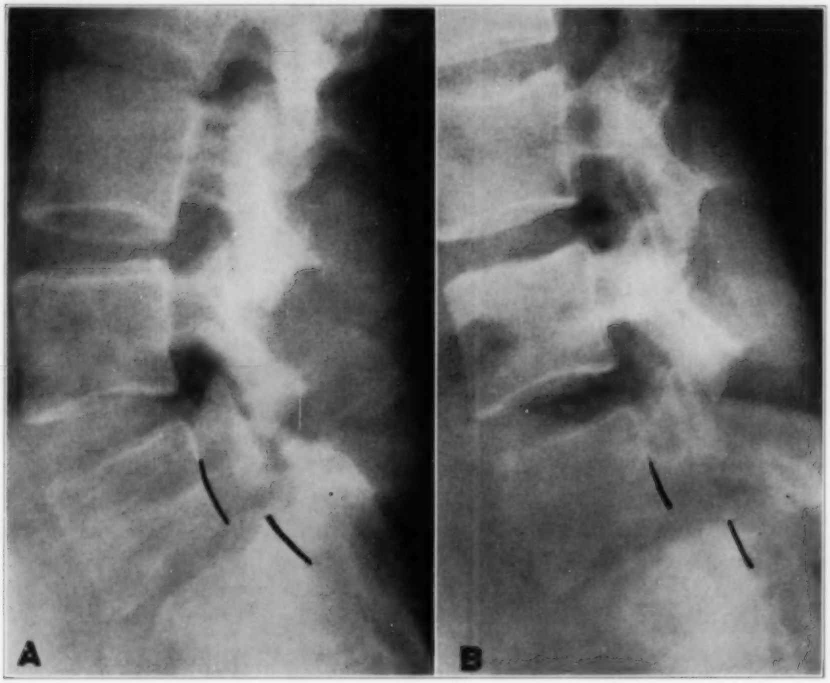

Fig. 15

Lateral roentgenograms show an apparent increase of spondylolisthesis due to an alteration in the position between flexion and extension. This demonstrates that lateral roentgenograms of the spine must be taken in relatively the same position. Apparent replacement, increase in slipping, or stability of the affected area can only be confirmed by insisting on this.

bed on the seventeenth postoperative day. A lumbosacral belt was worn in most instances when the patients got up. Occasionally a Knight brace was used instead, if the patient had been wearing this prior to seeing us. Such support was worn for an average time of nine months, the minimum being four months and the maximum two years.

Complications: There was one infection and one hematoma. The latter healed *per primam* following evacuation. In one patient, the dura was lacerated during operation without apparent ill effects. There were no operative mortalities.

Findings at Operation

Pars interarticularis: The defect in the laminar arches found at operation were of four definite types: (1) thin and tenuous fibrous bands bridging the defect, (2) thick and heavy fibrous columns in the same location, (3) a bony bridge across the portion of the arch where a defect had been suspected, and (4) a false joint. Combinations of these, such as a fibrous attachment on one side and a pseudo joint on the other, were also found. Plaques of bone within the fibrous bands were seen occasionally; these may represent early or abortive attempts at reossification of the defects (Figs. 12, 14-A, 14-B and 14-C).

At operation it was noted that the fibrocartilaginous structure within the defect did not seem to supply much support when compared with that supplied by the ligamentum flavum and the retained arch. Most of the stability at the involved interspace appeared to result from the imbrication of the fourth lumbar arch behind that of the fifth. Marked hyperplasia of the fibrous tissue within the defect, as described by Gill, has not been observed by us.

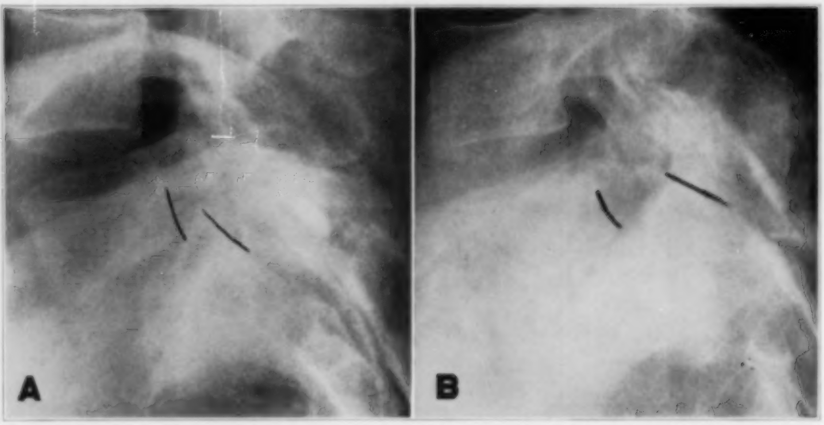

FIG. 16

Nineteen of sixty-four patients following the operative procedure showed measurable progression of the slipping before solid fusion had been obtained.

Nerve roots: Compression of the nerve roots by the fibrous tissue in the defect or by hypertrophic changes developing about the margins of the defect was not observed. In both instances, the roots lie anterior, out of the way. No true adhesions of the dura or nerve roots to the surrounding structures were observed. However, the epidural veins were usually increased both in number and in size. Bleeding was almost always greater than that during lumbar explorations for herniations of an intervertebral disc. The dural sleeves surrounding the nerve roots were frequently imbedded in these vascular channels.

Our failure to find evidence of nerve-root compression at operation was in keeping with the objective clinical findings in this series which rarely were consistent with nerve-root pressure.

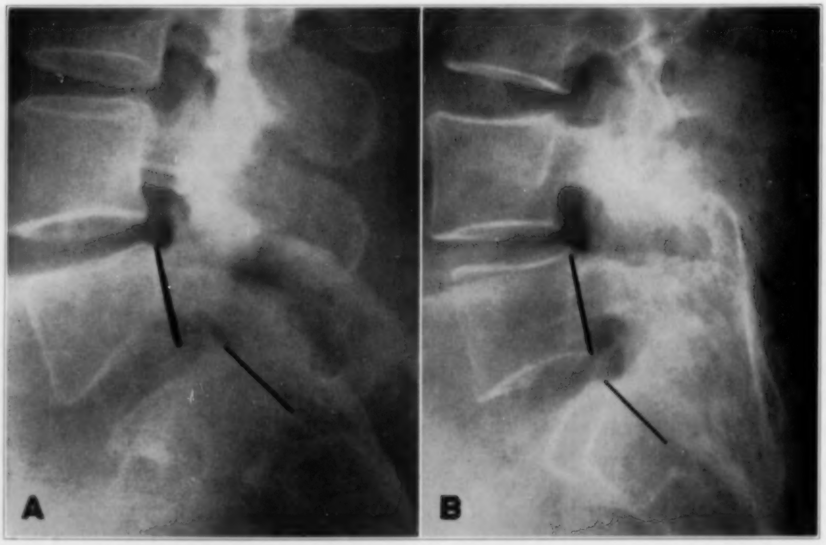

FIG. 17

Replacement of the affected vertebra incidental to the insertion of an H-graft occurred.

Ligamentum flavum: The ligamentum flavum attached to the inferior margin of the loose laminar arch was usually thickened to a slight extent. By contrast, the ligament attached to its upper margin was considerably thickened.

The defective arch: In spondylolisthesis of the fifth lumbar vertebra, the arch was usually somewhat smaller than would have been anticipated. Rotation of this arch often accentuated this appearance for, when first exposed, only the inferior margin was visible, the remainder being obscured beneath the lamina of the fourth lumbar vertebra. Frequently an arch, which at first appeared to be small, after removal was found to be normal in size. In the roentgenogram, the lamina of the fifth lumbar vertebra often appeared more dense and sclerotic than is normal, by reason of this same rotation. In contrast to this, spondylolisthesis at the fourth and third lumbar interspaces was not associated with this abnormal appearance of the arch.

Articular facets: The facets of the first sacral vertebra were essentially normal in size and were generally adequate for stability. Although small facets were seen, complete absence of these structures was not observed. Degenerative changes were observed in the cartilaginous surfaces of the exposed facets.

Approximation of the fourth laminar arch to the first sacral facets: In thirty-four patients with spondylolisthesis of the fifth lumbar vertebra, the sacral facets were in close proximity to the inferior border of the fourth laminar arch (Fig. 6). This, of course, shortens the gap to be bridged by the fusion.

Stability of the H-graft and quantity of bone for grafting: In four patients in whom a distraction type of graft was used, there was no spinous process at the lower end of the fusion area. Hence, the anterior surface of the graft merely lay on the dorsum of the sacrum. In sixteen patients, it was difficult to obtain an adequate amount of bone for fixation because the posterior portion of the ilium was unusually thin. The results in these patients were the same as in the series as a whole.

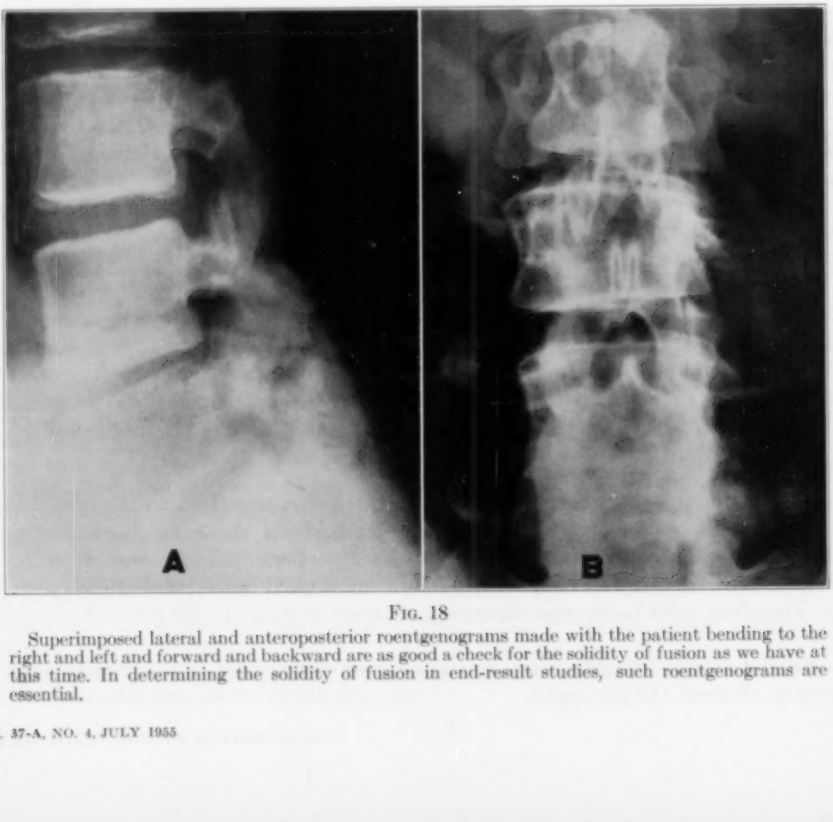

Fig. 18

Superimposed lateral and anteroposterior roentgenograms made with the patient bending to the right and left and forward and backward are as good a check for the solidity of fusion as we have at this time. In determining the solidity of fusion in end-result studies, such roentgenograms are essential.

OPERATIVE RESULTS

Postoperative Progression of Spondylolisthesis

Since the apparent degree of spondylolisthesis may be changed in the lateral roentgenogram by flexion or extension, lateral views in comparable positions are essential in order to determine any change in the amount of slipping (Fig. 15).

Increase of the spondylolisthesis postoperatively was found only among the sixty-four patients from whom the arch had been removed at the time of operation. Measurable progression of the deformity was found in nineteen (30 per cent.) of these. There were no symptoms referable to this additional slipping. This finding provides one of the clearest indications that the interposed laminar arch does offer some support by preventing forward slipping.

Among the nineteen patients with progression of the spondylolisthesis postoperatively, pseudarthroses developed in five (26 per cent.), while in the remaining fourteen (74 per cent.) fusion became solid. The average postoperative increase of slipping among the five patients with pseudarthrosis was 9 per cent., while in the fourteen patients with solid fusion the average increase was 16.5 per cent.

Among the five patients with pseudarthrosis, there were several factors responsible for the limited amount of forward slipping. In two instances, the fusion was intact between the sacrum and the pedicles of the displaced vertebrae. In two others, the graft had fused at its upper end to the fourth lumbar vertebra and overlapped the dorsum of the sacrum below, thereby forming a block to further slipping, even in the absence of fusion to the sacrum. In the remaining patient, with a spondylolisthesis at the third lumbar interspace, pseudarthroses developed at all interspaces between the second lumbar vertebra and the sacrum. At this high level in the lumbar curve, the tendency to forward slipping is minimal, since the interspace is nearly horizontal and the stress is primarily vertical compression.

On occasion, the wedging or distraction effect of the clothespin graft was found to have produced some correction of the spondylolisthesis (Fig. 17); in several instances the graft had produced some widening of the interspace and of the intervertebral foramina between the fifth lumbar vertebra and the sacrum. A distraction-type graft has never produced further slipping in our experience.

Among the patients in whom solid fusion developed, as demonstrated by superimposed roentgenograms made with the patient bending in two planes, no increase of slipping occurred after the fusion became solid.

Since, in our experience, a spine fusion generally becomes solid before the fifth postoperative month, it would appear that the increased slipping, noted in the patients with fusion, must have occurred within this five-month period.

Increase of the spondylolisthesis postoperatively did not seem to be related to such factors as the age of the patient, duration of symptoms before operation, or trauma at the time of onset. However, there did seem to be a definite relation to the amount of extrusion or rotation of the involved arch and to the amount of narrowing at the corresponding interspace. Of the nineteen patients who showed postoperative slipping, all had rotation or extrusion of the arch preoperatively and fifteen had narrowing of the interspace.

Results of Fusion

Two of the seventy-five patients died of carcinoma unrelated to the lumbar spine before the solidity of the fusion could be determined. Of the remaining seventy-three patients, sixty-two (85 per cent.) had solid fusion after the initial operation. In eleven (15 per cent.) pseudarthrosis developed. Repair was attempted in five, and fusion resulted in four. Therefore, solid fusion was ultimately obtained in sixty-six (90 per cent.) of the patients.

In all, fusion of 156 interspaces was attempted with success at 137 (88 per cent.) and failure at nineteen (12 per cent.).

Pseudarthrosis occurred four times at the third interspace, ten times at the fourth, and five times at the fifth. It would appear that pseudarthrosis is most likely to develop at the fourth lumbar interspace.

Relief of Symptoms

Among the seventy-three patients evaluated, sixty-five (89 per cent.) were asymptomatic. Of the sixty-six with solid fusion, sixty-two (94 per cent.) were free of symptoms; of the seven with failure of fusion, only three (43 per cent.) were asymptomatic.

Among the seven patients with pseudarthroses, four had continuous pain. Two of these were recorded as working, but the other two were disabled when last seen. Of the four patients with solid fusion who still had pain, all were at work.

CONCLUSIONS

1. The forward slip of the vertebral body and the defect in the pars interarticularis in spondylolisthesis represent only a part of the anatomical alteration present in such cases.
2. The arch of the displaced segment tends to provide support for the spine and to prevent further slippage. Removal of the arch is advisable, but only if replaced by a bone graft to give adequate support.
3. Pain in spondylolisthesis is the result of more than one etiological factor. We believe it to be due to impingement of malaligned bony elements and to abnormal stress on fibrous or ligamentous structures.
4. Extradural pressure from prolapse of an intervertebral disc occurs occasionally. Pressure from hypertrophied fibrocartilaginous tissue in the pars interarticularis defect has not been noted by us. Disc degeneration *per se* cannot cause pain.
5. Spine fusion by the technique described can be obtained in 85 per cent. of patients primarily and in 90 per cent. following repair of pseudarthroses. Relief of symptoms resulted in 89 per cent. of the patients with solid fusion.
6. Once solid fusion has been obtained, bony support of the weakened area is not only re-established, but it is permanent.

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DISCUSSION

Dr. R. I. Harris, Toronto, Ontario, Canada: I shall limit my remarks to one aspect of the problem of spondylolisthesis,—that of the surgical treatment.

I have now personally treated over 200 cases of spondylolisthesis. From this experience, I have reached the conclusions that surgical treatment of this lesion is the only one which offers hope of complete relief of the patient's symptoms and that the essential step in surgical treatment is operative fusion of the involved segment of the spine. I am, therefore, in full agreement with Dr. Bosworth and his associates on this point. My experience fully supports theirs,—that a successful lumbosacral fusion gives the patient complete relief of his symptoms.

It has recently been stressed that removal of the loose posterior segment of the neural arch is a simple operation which will relieve the patient of his pain. I have no doubt that removal of the loose segment will often relieve nerve-root pressure and hence relieve the sciatic pain which often accompanies spondylolisthesis. It does nothing, however, for the unstable vertebra which can and does continue to slip forward on the vertebra below. Only stabilization of the affected segment of the spine can solve this problem.

Pain in spondylolisthesis is of two origins: (1) low-back pain from the unstable vertebral body and (2) sciatica from nerve-root pressure. Such pressure can develop in two ways. First, nerve-root pressure can be due to protrusion of the disc. This is not common. When it does occur it is usually unilateral and, in the case of spondylolisthesis of the fifth lumbar vertebra, it involves the first sacral nerve root. Second, it can develop by distortion and diminution in the size of the intervertebral foramina between the fifth lumbar vertebra and the first sacral vertebra. This form usually is bilateral and involves the fifth lumbar nerve roots.

It has not been emphasized sufficiently that movement is an important factor in the production of pain in spondylolisthesis,—not only the pain due to instability of the vertebral body but also that due to nerve-root pressure. The elimination of movement by a successful lumbosacral fusion is sufficient to relieve the patient of his symptoms. This applies to the sciatica, as well as to the low-back pain. Whether the sciatica results from disc protrusion or from contraction of the intervertebral foramen, movement is the final factor which produces the pressure on the nerve root and the pain. Consequently lumbosacral fusion alone will cure the pain of spondylolisthesis, without exploration of the disc and without removal of the loose posterior segment of the arch.

How can we most easily and most certainly secure fusion in the operative treatment of spondylolisthesis? There is no easy answer to this question. Lumbosacral fusion for spondylolisthesis is undoubtedly the most difficult of all spine fusions. It taxes the ingenuity and skill of the best orthopaedic surgeons. Every craftsman doubtless will develop his own particular technique and, by constant use, perfect its details. My experience leads me to believe that certain principles are important. These are:

1. In the common spondylolisthesis of the fifth lumbar vertebra, the fusion should not extend above the fourth lumbar vertebra—this would place undue stresses upon the area of fusion and invite failure;
2. The posterior half of the neural arch should not be removed but left in place as an island of living bone from which the grafts can be revascularized and reorganized into living bone;
3. The major graft should extend in one piece throughout the whole field of fusion, and it should be firmly secured in some way to the spine and the laminae;
4. Cancellous bone should be used, as well as cortical bone;
5. The patient should be kept recumbent and still for an adequate period of time—a period long enough for fusion to become sufficiently solid to resist average stresses. Four months' recumbency is a minimum period. A brace should be worn for at least a year.

Dr. William H. Bickel, Rochester, Minnesota: I have enjoyed Dr. Bosworth's paper; he presents some new and interesting aspects of one type of backache which in the past has been amenable to cure by the orthopaedist at a gratifyingly high rate. Spine-fusion techniques are many, and most, when well done, will result in approximately the same percentage of solid fusion with relief of symptoms, if the cases are well chosen.

The subject of current debate is whether or not to keep the loose arch and whether or not, if the arch has been removed, to fuse.

Dr. Bosworth indicates that even the loose arch affords some stability to the spinal column when the slippage reaches 20 per cent. Nineteen of sixty-four patients (29 per cent.) who had the arch removed showed measurable slippage postoperatively before the fusion became solid; in five of these pseudarthrosis developed.

(Continued on page 797)

BONY MASSES PROJECTING INTO THE SPINAL CANAL OPPOSITE A BREAK IN THE NEURAL ARCH OF THE FIFTH LUMBAR VERTEBRA*†

BY LEE A. HADLEY, M.D., SYRACUSE, NEW YORK

The defect in the isthmus of the neural arch of the fifth lumbar vertebra, present in about 5 per cent. of all adult spines, was long held to be of congenital origin. The presence of two ossification centers for each side of the arch was postulated as a result of unconfirmed reports by Rambaud and Renault in 1864. Rowe and Roche, however, in reviewing the studies of 509 foetal spines, including their own series of fifty-three stillborn infants, were unable to find any evidence of a congenital defect in the isthmus of the neural arch of the fifth lumbar vertebra at that early period in life. Fifty spines of foetuses and newborn infants studied by this author in the Anatomy Department of The New York State Medical College at Syracuse showed only one ossification center for each side of the neural

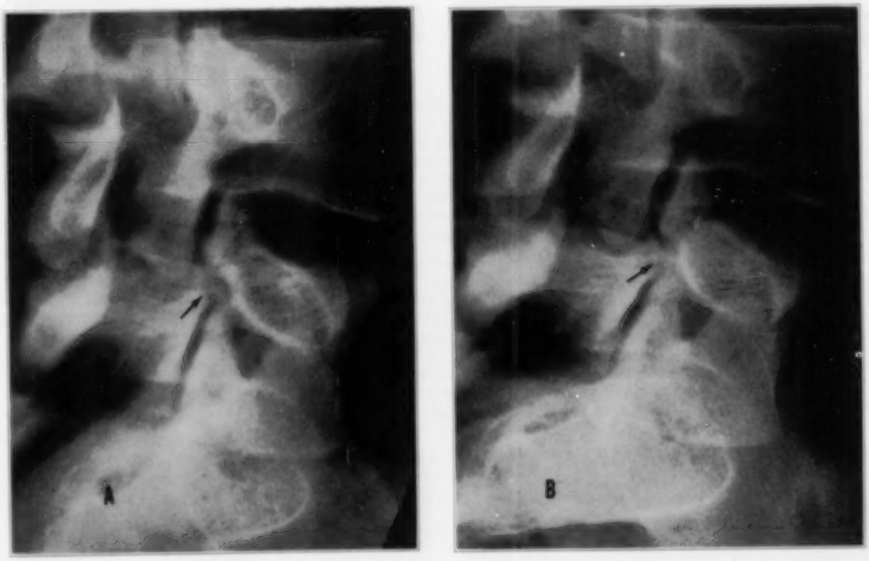

Fig. 1-A

Fig. 1-B

A male, aged eighteen. After a tackle during a football game, this patient emerged from a pile of players with severe localized pain in the back. He had never previously suffered such a condition. When examined eleven months later he complained of "grating" and pain in the right iliolumbar area which sometimes radiated down the right lower extremity. This was aggravated by dorsal extension. There was finger-point tenderness over the right side of the neural arch of the fifth lumbar vertebra and palpable crepitation over this area upon movement of the back.

Fig. 1-A: The roentgenogram made eleven months after injury showed a unilateral break in the neural arch of the fifth lumbar vertebra (arrow) with evidence of fragmentation of bone tissue at this point. When seen two years after injury the patient still complained of right-sided back pain and "grating" upon dorsal extension, but this author was no longer able to palpate the crepitation at that time.

Fig. 1-B: Re-examination five and one half years after injury showed resorption of the fragmented bone tissues. The appearance was that of a clean-cut ununited fracture (arrow).

A photomicrograph of a somewhat similar condition taken from cadaver material was published by this author in 1954. The case here illustrated is obviously a case of unilateral fracture of the neural arch of the fifth lumbar vertebra. In this instance callus formation did not develop and, therefore, the case is not included in Table I.

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* Based upon an exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26–31, 1952.

† Revised manuscript received May 12, 1955.

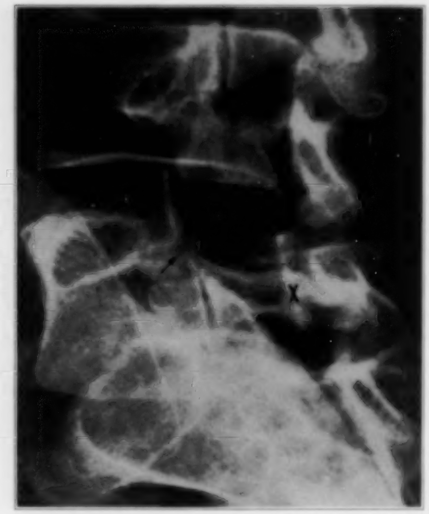

FIG. 2-A

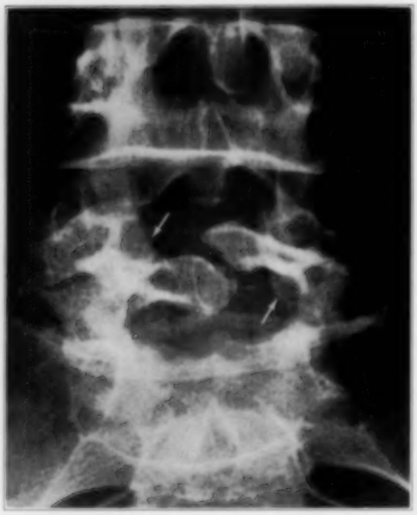

FIG. 2-B

Case 11, a female, thirty-four years old. While walking on a slippery incline, this patient fell, landing heavily on the buttocks. She was pregnant at the time. She immediately suffered severe pain in the region of the lower back. She had never experienced a similar pain previously. The pain gradually subsided in severity, to be replaced by a constant discomfort of the lower back which was present at the time of the x-ray examination six months following injury. There was no sciatica. The discomfort was not aggravated by movements of the back. She had undergone normal labor without difficulty. Straight-leg raising was tolerated to 45 degrees on each side. The Achilles reflexes and the left patellar reflex were active, but no patellar response was elicited on the right side.

Figs. 2-A and 2-B: The roentgenograms showed a bilateral break in the neural arch of the fifth lumbar vertebra, some spondylolisthesis, and forward displacement of the pedicle of the fifth lumbar vertebra with its attached laminar fragment (*X*). The black arrow (Fig. 2-A) indicates the break in the neural arch of the fifth lumbar vertebra as seen on the left oblique view. Small bilateral bony masses were present (Fig. 2-B, white arrows). Congenital non-closure of the neural arch of the fifth lumbar vertebra may have been a factor of weakness.

This patient was re-examined seven years after her fall. There were no significant symptoms. A comparative study of the roentgenograms showed virtually no change in the bone structure at the site of injury during this interval of six and one-half years.

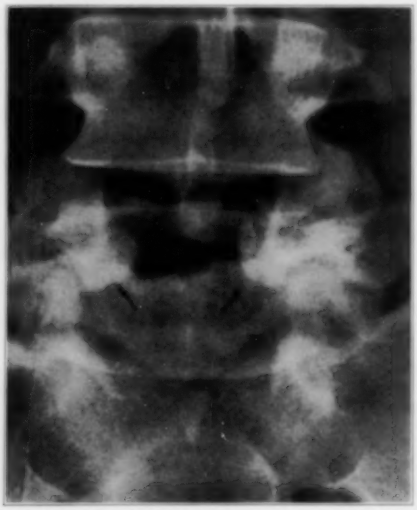

FIG. 3-A

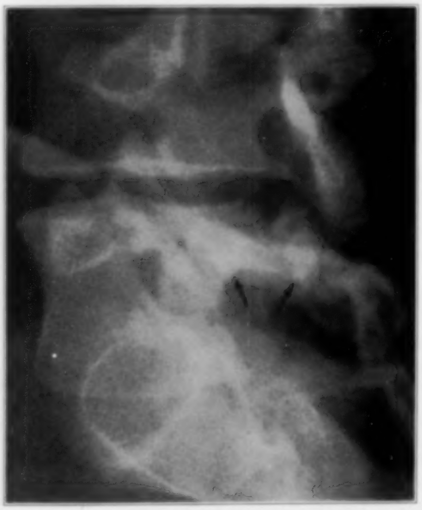

FIG. 3-B

Figs. 3-A and 3-B: Case 6, a male, aged twenty-two. He had fallen sixteen feet, landing on his back. His lower limbs were paralyzed for four hours. For the next four or five years he had recurrent attacks of weakness and loss of power in the lower extremities. There was local pain in the back during this time but no sciatica. The roentgenograms, made sixteen months after injury, revealed breaks in the arch of the fifth lumbar vertebra with bony masses (arrows) projecting into the spinal canal on each side. There was a first-degree spondylolisthesis.

Re-examination of this patient eight years after injury no longer showed motor disturbance of the lower limbs. The Achilles and patellar reflexes were normal. The patient did complain of periodic muscle spasm in the lumbar region. The roentgenographic re-examination showed the bony condition of the neural arch of the fifth lumbar vertebra essentially unchanged.

TABLE I

TWENTY-NINE PATIENTS WITH BONY MASS OR MASSES IN THE SPINAL CANAL DEMONSTRATED ROENTGENOGRAPHICALLY

Case No.	Initials	Age	Sex	Break in Neural Arch *	Bony Mass	Size of Mass†	Degree of Spondylolisthesis	History of Trauma, If Any
1	H.V.A.	11	M	B	B	+	First	Fell 7 feet from platform 1 year before.
2	J.C.	15	M	B	B	−	First	Fell 20 feet down hay shute to cement floor 6 years before.
3	J.P.	19	M	B	U	−	First	
4	F.C.	20	F	U	U	+	None	
5	D.J.	22	M	B	B	+	First	
6	P.S.	22	M	B	B	+	First	Fell 16 feet onto back 16 months before; was paralyzed 4 hours.
7	J.H.	25	M	U	U	+	None	
8	B.A.	29	M	B	U	+	None	
9	H.N.	29	M	B	B	+	First	
10	R.F.	31	M	B	U	−	First	
11	C.M.	34	F	B	B	−	First	Fell on buttocks 6 months before, with immediate severe pain.
12	M.M.L.	34	F	B	B	−	None	
13	W.W.	35	F	B	B	+	First	
14	D.H.	36	F	B	U	+	None	
15	H.P.	39	F	B	B	+	Minimal	
16	R.M.	39	M	B	B	+	First	Fell from staging one year before.
17	D.T.	40	F	B	B	−	None	
18	W.B.	42	M	B	B	+	First	
19	G.M.	44	F	B	B	+	First	
20	R.D.	45	M	B	B	+	First	
21	D.S.	47	M	U	U	−	None	
22	E.F.	49	F	B	B	+	First	
23	A.R.	50	M	B	B	+	First	
24	G.E.	52	M	U	U	+	None	
25	A.G.	52	F	B	U	+	Minimal	
26	A.H.	54	F	B	B	−	First	Severely injured playing ball 40 years before.
27	A.Z.	55	M	B	U	+	First	Had chair pulled from under him 30 years before.
28	T.B.	57	F	B	B	+	Second	
29	E.S.	61	F	B	B	+	Second	

* B, bilateral: U, unilateral.

† +, larger than diameter of the lamina; −, smaller than diameter of the lamina.

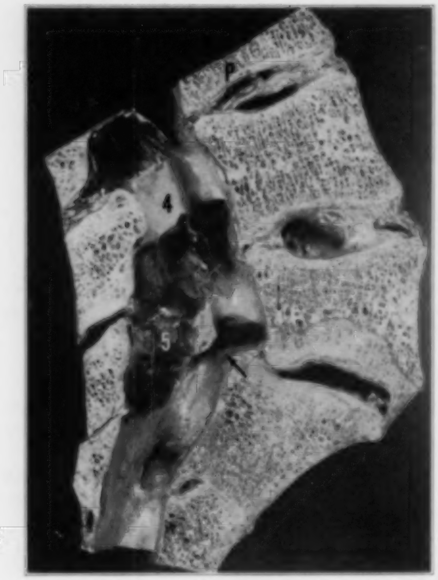

FIG. 4-A

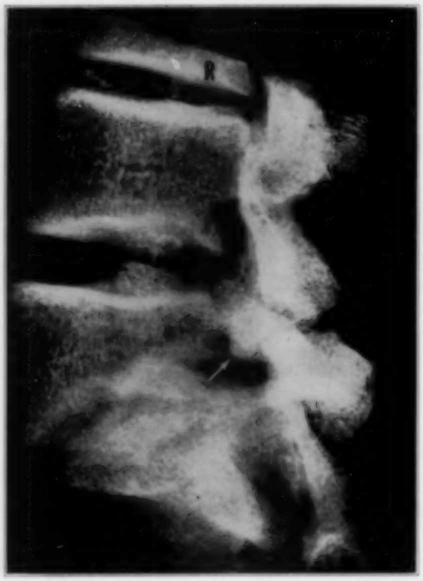

FIG. 4-B

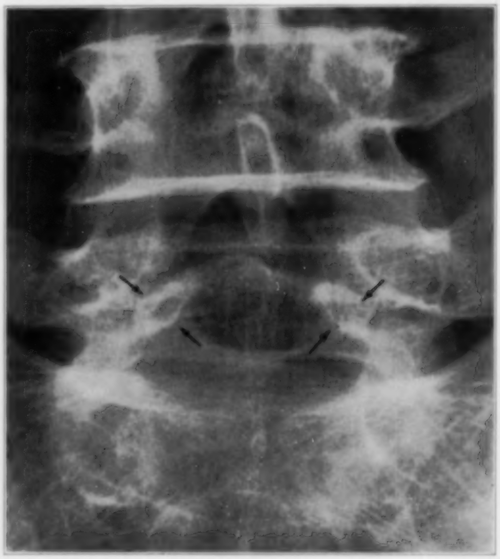

FIG. 5

Fig. 4-A: Photograph of a specimen showing a break in the neural arch of the fifth lumbar vertebra with first-degree spondylolisthesis. The neural arch of the fourth lumbar vertebra is intact from the spinous process to the vertebral body (*4*). The defect in the arch of the fifth lumbar vertebra is bridged by fibrous tissues at *5*. A part of the lamina of the fifth lumbar vertebra remained attached to the pedicle and was carried forward with that structure (arrow). This constitutes an encroachment upon the passage for the sacral nerve roots.

Fig. 4-B: Forty-five degree oblique roentgenogram of this specimen shows in profile the fragment of the neural arch which has been carried forward (arrow). The anterior surface of these shadows is usually flattened, as seen here and in Figs. 2-A and 2-B. This specimen did not show a separate bony mass such as that seen in Fig. 7-A.

Fig. 5: A male, aged sixty-four. There was a break in the neural arch of the fifth lumbar vertebra with a first-degree spondylolisthesis. The oval shadows enclosed by the arrows are formed by the cortex of the detached posterior portion of the neural arch. They are posterior and medial to the cortices of the corresponding pedicles. In order to produce such a shadow of the cortex, the roentgen ray must pass through, parallel to the surface of the bone at that point. These shadows are not to be mistaken for those of the bony masses described in this paper.

arch. This was true of all lumbar segments and of all specimens studied. Hitchcock believed that the defect may frequently result from a birth injury. Roche reported an adult with bilateral fracture of the pars interarticularis of a third lumbar arch, with healing two years and four months later. The lateral roentgenogram made at that time showed evidence of callus formation.

Fracture of the neural arch of the fifth lumbar vertebra by trauma undoubtedly does occur if trauma is sufficiently severe (Figs. 1-A through 3-B). Healing of a fracture at the isthmus of the fifth lumbar vertebra is probably more difficult because of the shearing stress and movement at that level.

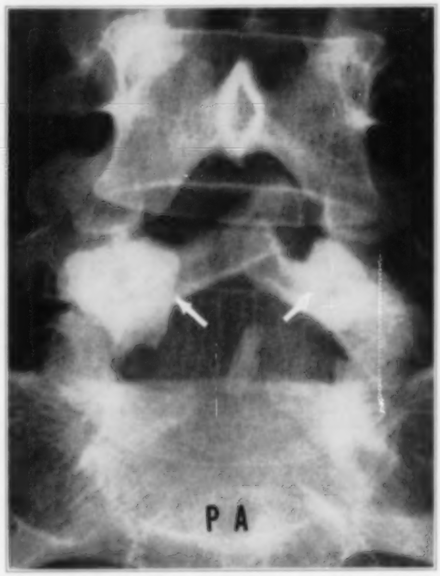

Fig. 6-A

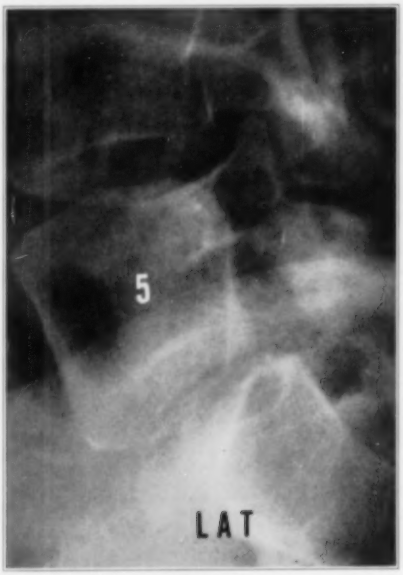

Fig. 6-B

Fig. 6-A: Case 19, a female, aged forty-four. No history of injury was obtainable. The postero-anterior roentgenogram showed callous masses on both sides (white arrows).

Fig. 6-B: The lateral roentgenogram showed minimal spondylolisthesis of the fifth lumbar vertebra.

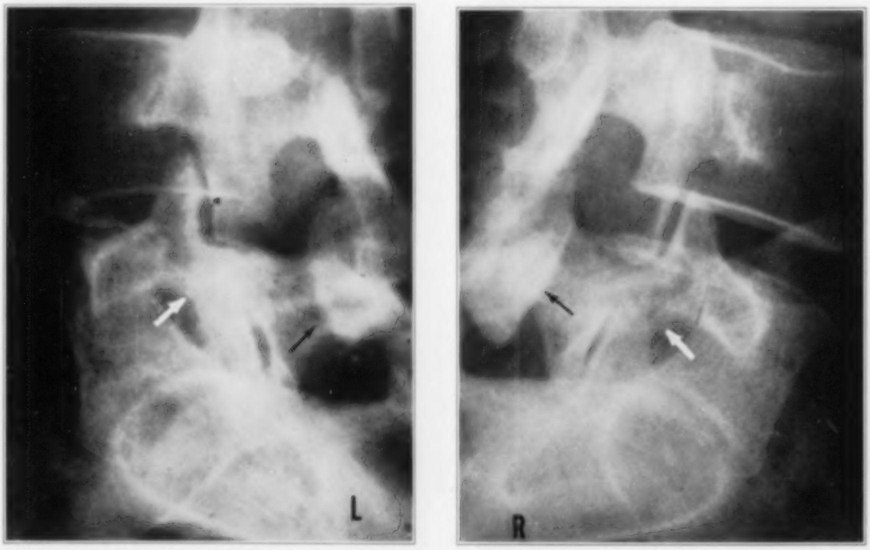

Fig. 6-C

Fig. 6-D

The right and left oblique roentgenograms showed the neural arch of the fifth lumbar vertebra to be intact on both sides (white arrows), but the calluses were seen posteriorly bulging into the spinal canal (black arrows). These are probably due to old healed fractures occurring early in life.

Of some interest in this connection is a series of private patients studied for low-back symptoms whose roentgenograms showed callus-like bony masses projecting into the spinal canal. In most of these there was a break in continuity of the neural arch of the fifth lumbar vertebra on one or both sides. (These patients had been referred for diagnosis only and no treatment was undertaken by this writer.) Seen in the postero-anterior view, the mass appears as a dense, circumscribed, rounded bone shadow bulging medially into the lumen from the lateral wall of the spinal canal.

Figures showing percentage incidence are not available. However, twenty-nine examples of this condition have been encountered in private practice during the past six years. Of these, sixteen were males and thirteen were females. The youngest was eleven years and the oldest, fifty-seven. Twenty

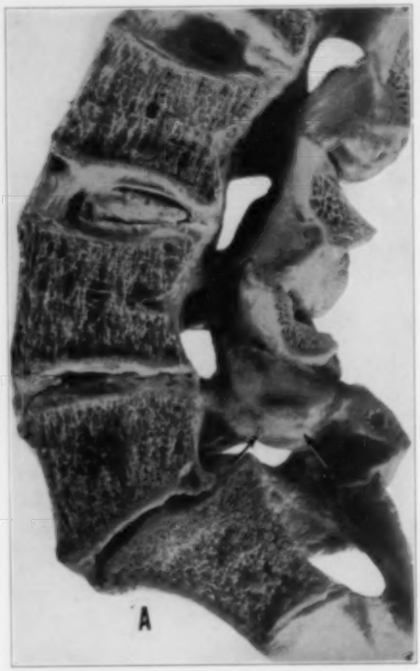

FIG. 7-A

Fig. 7-A: Saggital section from the cadaver of a male, seventy-four years old, with spondylolisthesis. There is an ossicle seven by twelve millimeters within the ligamentous tissue bridging the neural-arch defect (arrows).

Figs. 7-B and 7-C: Postero-anterior and left oblique roentgenograms of the same specimen. The mass projecting into the spinal canal is indicated by arrows. Note also the compensatory stabilizing impingements which have developed at various points, particularly between the tips of the superior articular processes of the fifth lumbar vertebra and the bases of the transverse processes of the fourth lumbar vertebra.

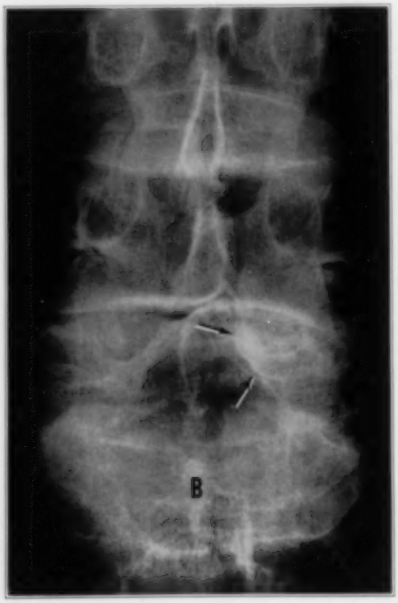

FIG. 7-B

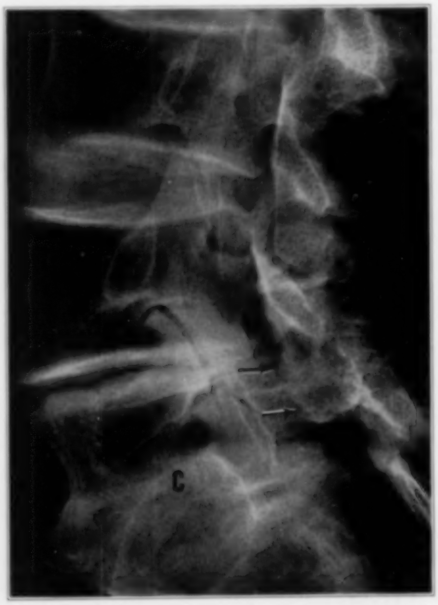

FIG. 7-C

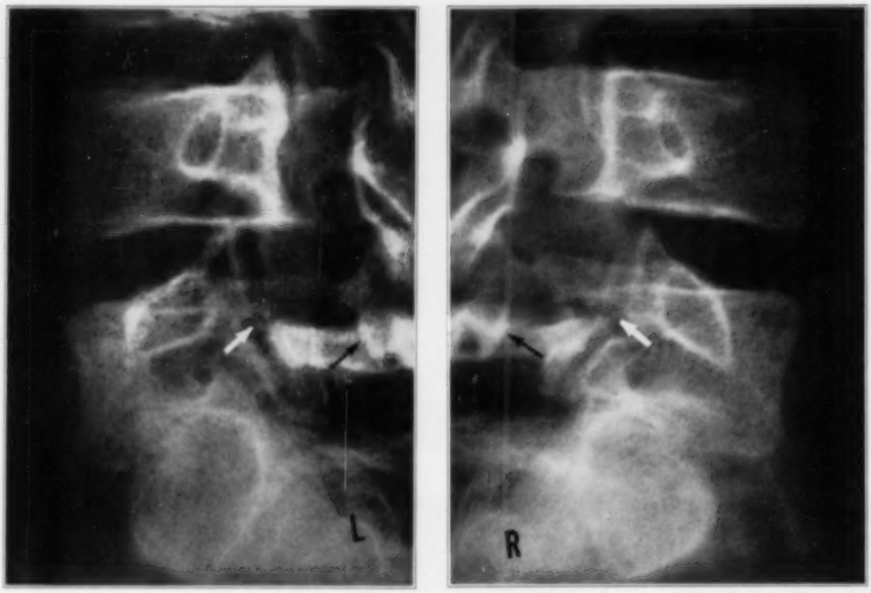

FIG. 8-A

FIG. 8-B

Case 1, an eleven-year-old male. He had fallen from a seven-foot loft one year before. The left and right oblique roentgenograms showed bilateral defects in the neural arch of the fifth lumbar vertebra (white arrows) and callous masses projecting from the laminae into the spinal canal (black arrows). The defect in the neural arch may be recognized as a "cross" shadow. The point of intersection is that space, free of bone, between the inferior articular process of the fourth lumbar vertebra and the articular process of the sacrum. This is shown particularly well in the right oblique view (point of white arrow).

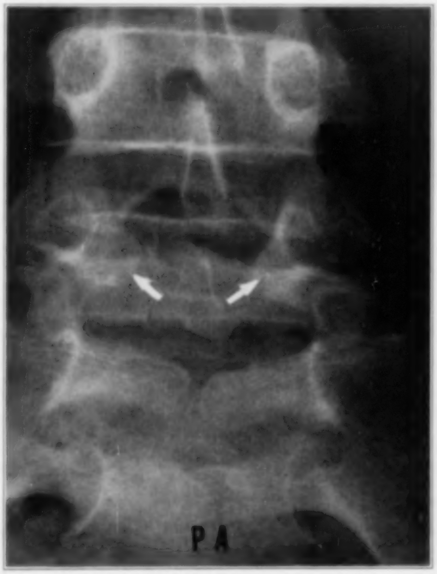

FIG. 8-C

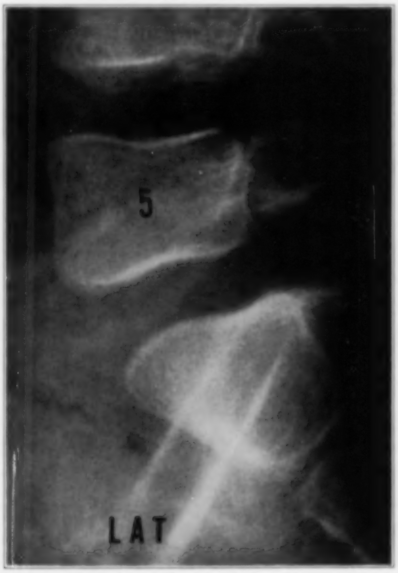

FIG. 8-D

Fig. 8-C: The postero-anterior roentgenogram showed the two rounded bony masses bulging into the spinal canal (white arrows).

Fig. 8-D: The lateral roentgenogram showed a first-degree spondylolisthesis, the fifth lumbar vertebra being displaced anteriorly onto the first sacral vertebra.

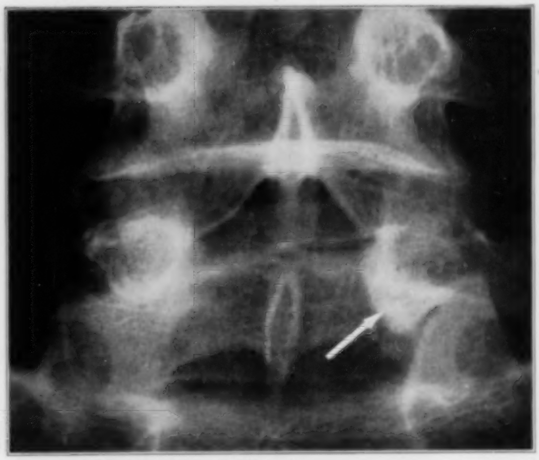

FIG. 9

Fig. 9: Case 21, a male, aged forty-seven. The patient stated that low-back pain began as he was pushing a truck while at work. The roentgenogram showed a unilateral break in the neural arch of the fifth lumbar vertebra on the right side, without spondylolisthesis. The presence of a bony mass is seen (white arrow), but no history of old injury could be obtained from this workman.

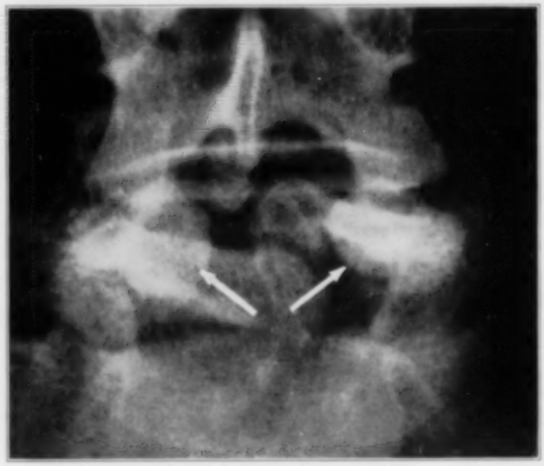

FIG. 10

Fig. 10: Case 16, a male, aged thirty-nine. The patient had fallen from a staging one year before examination. He complained of low-back pain with sciatic distribution, which was aggravated by movement. There was a bilateral break in the neural arch of the fifth lumbar vertebra with spondylolisthesis and formation of a bony mass on each side (white arrows). This patient wrote four and two-thirds years after injury that the pain continued to be severe and that he was still obliged to wear a steel brace.

patients showed some degree of spondylolisthesis, while nine were free of any vertebral displacement. In six there was a unilateral break in the neural arch of the fifth lumbar vertebra. Eleven showed the bony mass on one side only. The size of the mass was recorded as + if it was larger than the diameter of the lamina as seen in the oblique roentgenogram; if less than the diameter of that structure, it was designated as −. Ten patients complained of pain referred down one or both lower extremities. Only seven patients gave a history of trauma sufficiently severe to have caused a fracture of the neural arch of the fifth lumbar vertebra (Table I). Considerable encroachment upon the spinal canal resulted in some cases.

Roentgenograms of the lower portion of the spine are routinely made in the postero-anterior projection rather than with the patient supine. When the patient is lying face downward, the anterior lumbar curve allows the central ray to pass through parallel to the plane surfaces of nearly all of the vertebral bodies and the sacrum is not foreshortened. Depending somewhat upon the curvature of the spine, the distance between the lumbosacral junction and the film may be no greater when the patient is prone than it is when he is supine, because in the latter instance the part is elevated away from the table by the buttocks and the mid-thoracic portion of the spine. The oblique view is very important. For this the patient first lies on his back and then rolls up on his side until the transverse plane of his body forms an angle of between 45 and 60 degrees with the table top. The central ray is centered just below and anterior to the anterior superior iliac spine. With the left side lowermost, one may see the articulations and the pars interarticularis of the left side, while posteriorly appear the laminae and the bony mass of the right side.

Two possible sources of confusion have been encountered. In certain cases a small

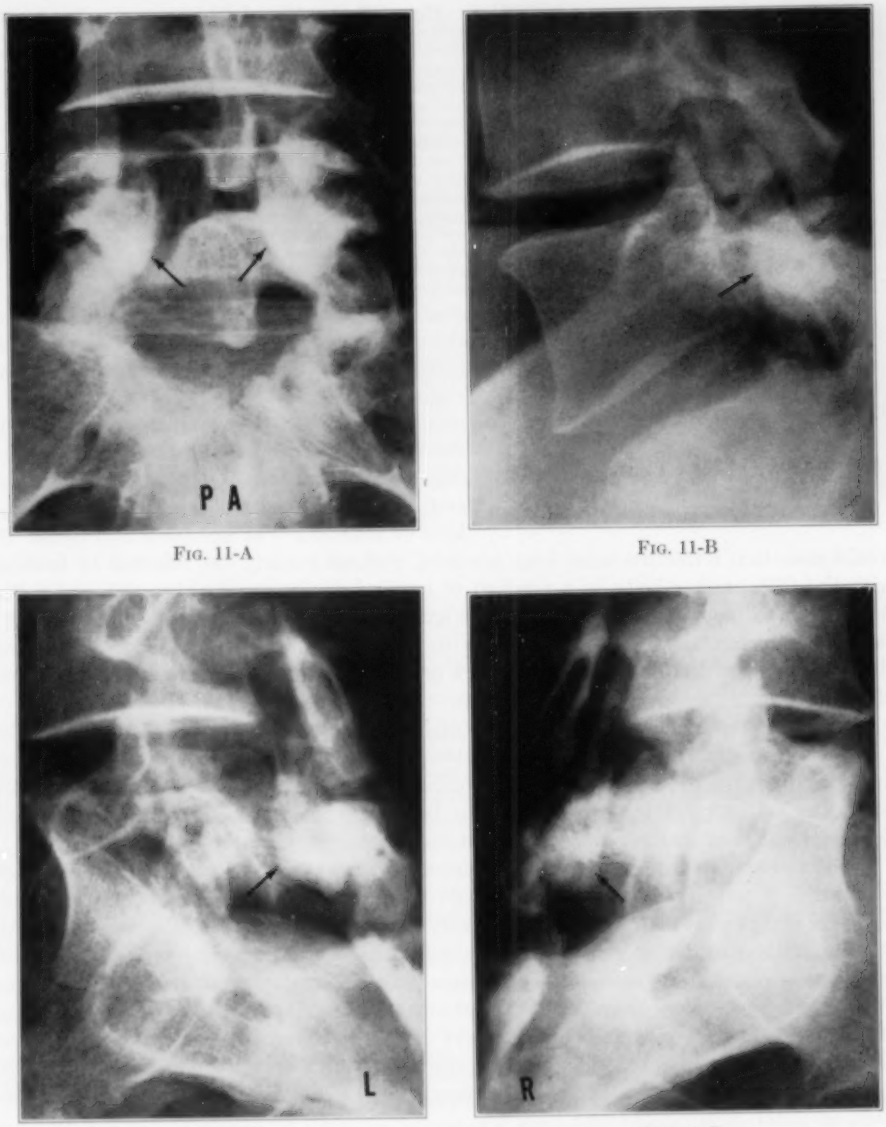

Fig. 11-A

Fig. 11-B

Fig. 11-C

Fig. 11-D

Figs. 11-A to 11-D: Case 22, a female, aged forty-nine. There was no history of accident. The patient had pain in the low back, radiating down the right lower extremity. The postero-anterior, lateral, and oblique roentgenograms showed bony masses projecting medially and forward into the spinal canal from the region of the neural arch of the fifth lumbar vertebra (arrows). There is no evidence of arch defect.

section of the lamina may remain attached to the pedicle and may be carried forward with that structure. In the oblique view the profile of this fragment, flattened anteriorly, must not be mistaken for the rounded bony mass described (Figs. 4-A and 4-B). The second source of possible error is occasionally seen in the postero-anterior projection, wherein the profile of the cortex of the detached lamina is visualized separate from, and medial to, the pedicle. Its outline is somewhat rounded like that of the bony mass; however, the

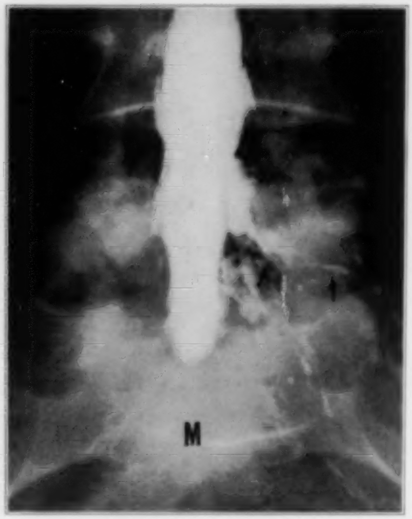

FIG. 11-E

Fig. 11-E: Myelography failed to reveal any disc protrusion and the bony mass did not press against the dura. The myelogram was made with the patient supine. Fortunately for this study, some of the opaque medium entered the epidural space and lay between the dura and the bony mass on the right side. The position of the fifth lumbar nerve root is indicated by the slender column of opaque material (arrows) which accompanies that structure. It will be seen that, as the nerve sweeps downward and laterally toward the intervertebral foramen, it is impinged upon and deflected medially by the bony mass. This case indicates that bony pressure may be exerted upon a nerve root without disc herniation into the spinal canal and that nerve-root pressure may be present without distorting the myelographic shadow.

shadow is not dense and homogeneous, since the medullary cavity is visualized in its center, surrounded by the more dense shadow of the cortex (Fig. 5).

One patient with no history of injury showed bilateral callus formation and first-degree spondylolisthesis. No break in the neural arch was visualized, but the pars interarticularis on each side was elongated and dense. It would seem that a fracture must have occurred, perhaps in early life, followed by healing with the fifth lumbar body in a position of forward displacement (Figs. 6-A and 6-B). Schmorl and Junghanns have shown as Figure 322 a similar roentgenogram from the cadaver of a man, sixty-eight years old, with spondylolisthesis, in whom the isthmus of the neural arch of the fifth lumbar vertebra presented a fusiform enlargement suggestive of callus formation.

Pheasant reported operative removal of a "separate ossicle of bone approximately 1 by 0.5 centimeter" underlying a defect in the isthmus and producing a "marked pressure upon the L_5 nerve root". The patient complained of nerve-root pressure symptoms and there was a history of injury four months before. A bony mass similar to those here described was seen on the preoperative but not on the postoperative roentgenograms.

Gill and his associates performed root decompression at the fifth lumbar intervertebral foramen in a series of over twenty patients with spondylolisthesis who complained of radicular symptoms. They had found in every case a mass of fibrocartilaginous tissue at the site of the pseudarthrosis producing compression of the fifth lumbar root. Excellent results were obtained by removal of this mass. In a personal communication, Gill wrote: "Several of our patients have had additional bony ossicles present in the pseudoarthrosis at the defect in the pars interarticularis and these have likewise been relieved." In four cases the ossicles were unilateral and in one case they were bilateral. He further stated that "the additional fragment of bone present was in such a position as to cause further compression of the fifth lumbar root".

The roentgenogram of one of our anatomical specimens (Figs. 7-A, 7-B, and 7-C) showed a mass at the neural-arch defect. This contained an ossicle seven by twelve millimeters in size. In another specimen, also from the Anatomy Department, New York State School of Medicine, Syracuse, a similar though somewhat smaller ossicle was present.

Bony formation may result from a rubbing of the bony surfaces together. Specimen No. 278 from the Terry Anatomical Collection at Washington University, which has a bilateral break in the neural arch of the fifth lumbar vertebra, reveals a substantial mass of bone projecting medially from the left pedicle into the canal adjacent to the defect in the neural arch.

Postero-anterior and oblique roentgenograms of our patients clearly show encroachment of the spinal canal by these dense, rounded bony masses. In one case, the presence of such a mass was confirmed by myelography. The probability of callus formation in this connection must be entertained (Figs. 8-A through 8-D, 11-A, 11-B, and 11-C).

NOTE: These studies were assisted by the Departments of Anatomy and Photography, New York State School of Medicine, Syracuse, New York.

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DISCUSSION

SPONDYLOLISTHESIS

(Continued from page 786)

He also observed at operation that there was no fibrous hyperplasia in the defect of the pars interarticularis, that there was no compression of the nerve roots by fibrous tissue, that there was no compression by hypertrophic changes, and that there were no dural adhesions. In only one of sixty-one patients from whom the arch was removed was a protruded disc found. This, I believe, represents a somewhat lower rate than reports that have been published.

From this I would conclude that the arch is doing no harm and may be affording some stability—so why remove it? Removal adds to the operative trauma, as it can be difficult, and to the residual extradural scar-tissue formation.

When any bone graft is placed, it is axiomatic that maximal contact be made between the graft and living bone. The normal laminae and spinous processes have a good blood supply, and most deficient arches found in spondylolisthesis have adequate circulation, as can be demonstrated at operation when the arch is prepared. A flat surface for the graft can be obtained by rongeuring away the prominent portion of the loose arch, and its blood supply will add to the nourishment of the bone graft and enhance the chances of union. The remaining portion of the arch also serves to protect the cauda equina.

I would be the first to remove the loose arch were there a question of its causing symptoms by nerve-root pressure, or if the procedure would aid in the removal of a protruded disc or in decompressing the cauda equina, but I question the advisability of removing the arch routinely when stability is all that is desired.

DR. BOSWORTH (closing): We would re-emphasize that there are several reasons for removal of the arch of the displaced vertebra. Without its removal, a straight distraction graft often cannot be placed. The blood supply of the denuded loose arch is markedly decreased and some of these arches are sclerotic and practically avascular. If left *in situ* they do not form an island of living bone but represent an avascular area which must be crossed. With the loose arch of the fifth lumbar vertebra removed, the gap between the arch of the fourth lumbar and the facets of the first sacral segment is small. This gap, especially in severe spondylolisthesis, is much less difficult to bridge than the denuded arch. One must see the situation with the arch removed at operation to understand this. Contact of the pedicles of the displaced segment with the main body of the graft can be gained through chip grafts only by removing the arch. We have shown that such contact can produce solid bony continuity between the displaced body and the main portion of the graft.

It has been a pleasure to submit this paper for your consideration.

A COMPREHENSIVE EXPOSURE OF THE HIP JOINT

BY FLOYD JERGESEN, M.D., AND LEROY C. ABBOTT, M.D., SAN FRANCISCO, CALIFORNIA

From the Department of Orthopaedic Surgery, University of California School of Medicine, and the Veterans Administration Hospital, San Francisco

Extensive exposure of the region of the hip joint may be necessary for resection of the upper end of the femur, arthrodesis, or arthroplasty. Limited surgical exposure for arthroplasty may not allow adequate treatment of the articular capsule, acetabulum, or both. Thus, the success of arthroplasty can be limited by the inadequacy of the exposure.

The surgical approach to be described gives complete exposure of all aspects of the hip joint. Major nerves and blood vessels that might be injured are demonstrated in order to allow protection. The important retinacular blood supply of the head and neck of the femur carried by the medial and lateral circumflex femoral vessels is preserved. Rapidity of execution and simplicity of anatomical detail are not attributes of this operation. During the past six years, we have used this exposure or minor variations of it more than seventy-five times with increasing enthusiasm.

HISTORICAL

This exposure is derived from certain classical approaches to the hip joint. Charles White first suggested the possibility of resection of the upper end of the femur through a lateral longitudinal incision centered over the greater trochanter (Fig. 1-A). More than fifty years elapsed before Anthony White successfully executed that operation. For the same purpose, Velpeau proposed a semilunar incision, convex inferiorly, starting at the anterior superior iliac spine and ending at the ischial tuberosity (Fig. 1-A). The earlier operations for resection of the upper end of the femur differed primarily in the configuration of the skin incision. The rest of the operation was executed in a bold and rapid fashion, the remainder of the soft tissues being divided close to the bone. The detailed anatomy of surgical approaches to the hip joint was not emphasized until anaesthesia allowed the development of a more leisurely operative technique. Sayre made use of the interval between the tensor fasciae latae and the glutaeus medius for resection of the upper end of the femur (Fig. 1-A). Ollier described a semilunar incision that permitted exposure of the hip joint by osteotomy of the greater trochanter and mobilization of the glutaeus medius and glutaeus minimus muscles (Fig. 1-A).

TECHNIQUE

Position

The patient lies with the affected side upward and the extremity draped free.

Skin Incision

Starting at the anterior superior iliac spine, the skin incision is made obliquely downward and backward over the summit of the greater trochanter, ending 5.0 centimeters below the gluteal fold and near the junction of the middle and outer thirds of the posterior surface of the thigh, which corresponds to the interval between the biceps femoris and the vastus lateralis (Fig. 1-B). The incision is extended below the buttock in order to free the glutaeus maximus.

Incision of the Superficial Fascia

The superficial fascia and fat are incised in the same direction as the skin. The proximal half of the posterior edge of this layer is undermined approximately 4.0 centi-

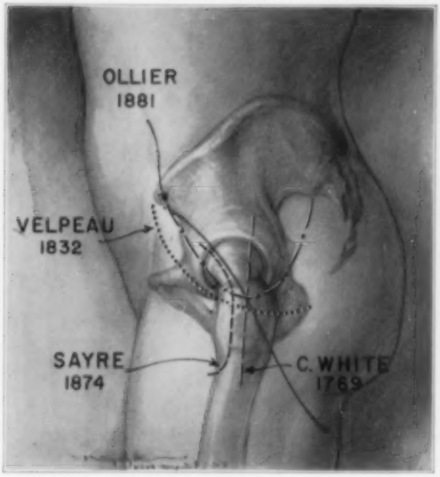

FIG. 1-A

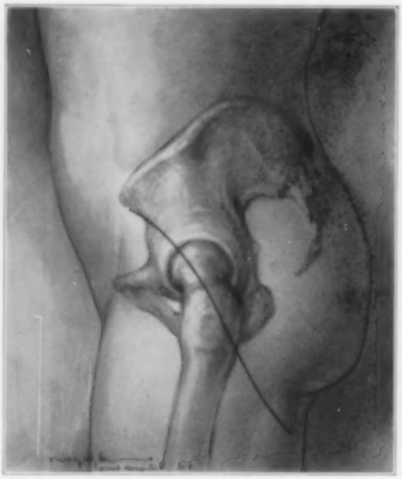

FIG. 1-B

Fig. 1-A: Historical derivation of this exposure of the hip joint.

Fig. 1-B: Relation of the authors' skin incision to the skeleton.

Fig. 2: Drawing showing the direction of the incision of the fascia lata.

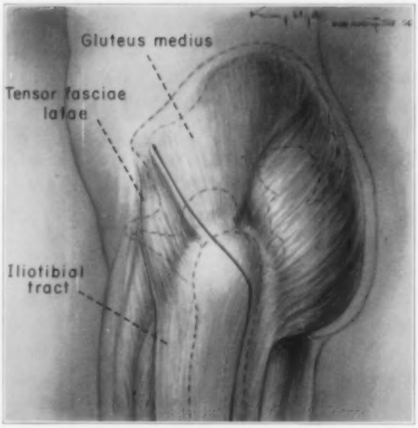

FIG. 2

meters, in order to demonstrate the origin of the tensor fasciae latae from the iliac crest (Fig. 3). The lower half of the anterior margin of the wound is dissected forward about 4.0 centimeters for subsequent identification of the insertion of the glutaeus maximus into the gluteal tuberosity.

Incision of the Fascia Lata

The direction of the incision in the fascia lata (Fig. 2) is determined by three landmarks: the dorsal border of the tensor fasciae latae, the region of the lateral surface of the greater trochanter, and the osseous insertion of the glutaeus maximus. It is preferable to start this incision near its middle. That portion of the iliotibial band lying over the greater trochanter is divided in the direction of the skin incision (Fig. 3). The trochanteric bursa is opened simultaneously. Abduction of the thigh facilitates the following manoeuvres. A finger is passed through the fascial incision in a medial and proximal direction along the dorsal border of the tensor fasciae latae as far as the iliac crest. This detaches the underlying fibers of the glutaeus medius from their aponeurotic origin.

The fascial incision is extended along this artificially produced plane of cleavage. Next, the palpating finger is inserted distally beneath the fascia lata to identify the anterior border of the osseous insertion of the glutaeus maximus. The incision is extended distally, parallel to the shaft of the femur, from the posterior border of the greater trochanter to the lower end of the gluteal tuberosity. This detaches a portion of the aponeurotic insertion of the glutaeus maximus and also exposes most of its osseous insertion. The edges of the fascia lata are retracted, bringing into sight the deep layer of the trochanteric bursa and the region of the greater trochanter.

Dissection of Muscle

Anterior portion: The anterior exposure takes advantage of the interval between the glutaeus medius and the tensor fasciae latae (Fig. 4). The dissection is made easier by flexion and external rotation of the thigh. With dissection starting at the greater trochanter, the fat is dissected from the ventral margin of the glutaeus medius. Distally and anteriorly, the fascia lata is separated from the underlying vastus lateralis. As the exposure is developed medially, the deep surface of the tensor fasciae latae is freed from the underlying glutaeus medius. Terminal branches of the superior gluteal nerve and vessels to the tensor fasciae latae are encountered in this interval, about 8.0 centimeters below the iliac crest or approximately midway between the trochanter and the anterior superior iliac spine (Fig. 4). The vessels and nerve are protected. The dissection is deepened. Careful separation of the fat from the ventral margin of the glutaeus medius will show the underlying deep layer of the fascia lata (Fig. 4). This fascial layer blends with the glutaeus medius near its insertion, and some of the ventral fibers of the muscle insert into it. Medially, this layer is found on the deep surface of the belly of the tensor fasciae latae, blending with the reflected tendon of the rectus femoris. Superiorly, it is attached to the joint capsule from the trochanter to the acetabulum. This deep layer can be identified easily by inserting the finger in a medial direction, close to the capsule, starting near the junction of the glutaeus medius and the vastus lateralis (Fig. 4). The fat is dissected from the anterior surface of the joint capsule to the intertrochanteric line. With continued dissection medially, the lateral border of the rectus femoris and its reflected tendon are exposed and are freed from the capsule (Fig. 6). Retraction of the rectus femoris exposes the lateral border of the iliacus. That muscle is separated from the underlying capsule. Medial retraction of the iliacus and the adjacent fat protects the lateral femoral circumflex artery and its articular branch (Fig. 6). This particular branch, when present, penetrates the iliofemoral ligament near the intertrochanteric line. The anterior exposure of the capsule is completed.

Superior portion: Reflection of the glutaeus medius and the glutaeus minimus with the attached greater trochanter exposes the superior aspect of the capsule of the hip joint. Extension and adduction of the thigh simplify the dissection. The ventral and superficial fibers of the glutaeus medius and the adjacent portion of the greater trochanter have been made visible by dissection of the overlying bursa and areolar tissue (Fig. 5). From the ventral aspect, a curved instrument is inserted in a posterior direction between the glutaeus minimus and the capsule adjacent to the greater trochanter. From the dorsal aspect, the freed border of the glutaeus maximus is retracted in order to identify the dorsal border of the glutaeus medius near its insertion. The dorsal border of the underlying glutaeus minimus can be identified by palpating the adjacent firm tendon of the piriformis. The piriformis tendon is separated from the tendons of the glutaeus medius and glutaeus minimus. The inferior branch of the superior gluteal artery and its accompanying veins are encountered in this region and they may require ligation. A second instrument is introduced between the glutaeus minimus and the capsule, being directed anteriorly close to the trochanter. The greater trochanter is now isolated and is ready for osteotomy (Fig. 5). Starting laterally, between the origin of the vastus lateralis and the insertion of the glutaeus medius, the osteotome is driven medially and superiorly at an angle of about 45 degrees to the shaft of the femur toward the junction of the trochanter and the neck. The deep cortex is not osteotomized but is fractured by wedging of the trochanter proximally. This avoids possible injury to any blood vessels carried in the superior retinaculum. The deep surface of the glutaeus minimus is dissected from the capsule as far as the acetabulum. After detachment of the deep layer of the fascia lata, the superior aspect of the capsule of the hip joint is exposed (Fig. 6).

Posterior portion: The capsule is exposed posteriorly by mobilization of the glutaeus

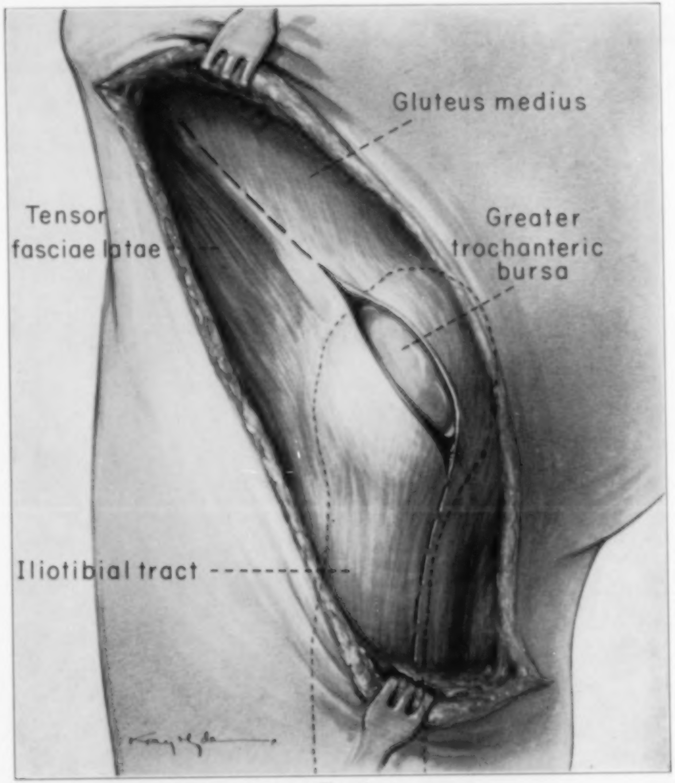
Gluteus medius
Tensor fasciae latae
Greater trochanteric bursa
Iliotibial tract

FIG. 3

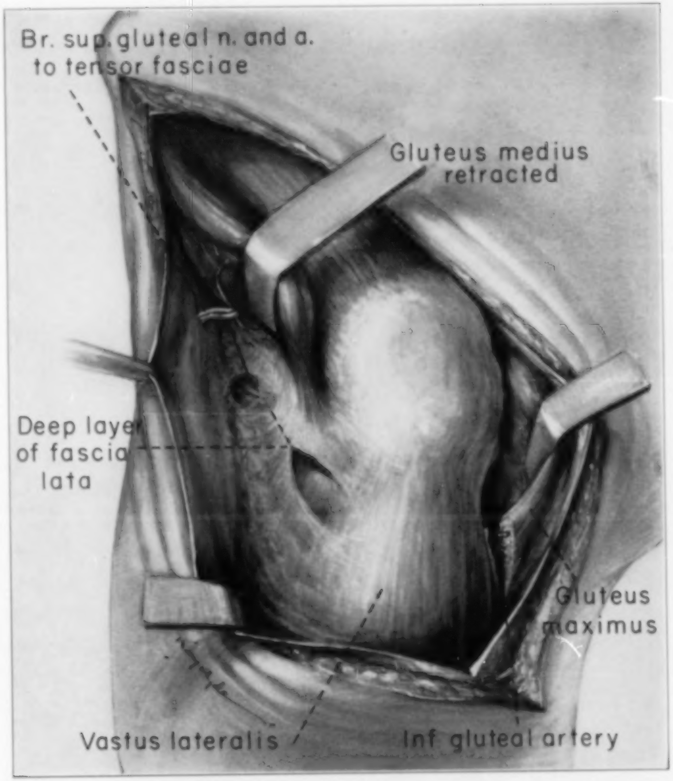
Br. sup. gluteal n. and a. to tensor fasciae
Gluteus medius retracted
Deep layer of fascia lata
Gluteus maximus
Vastus lateralis
Inf. gluteal artery

FIG. 4

Fig. 3: Showing the relation of the skin incision to the incision of the deep fascia. The anterosuperior and postero-inferior wound margins have been freed.

Fig. 4: Muscle dissection, anterior aspect. The ventral border of the glutaeus medius has been dissected from the overlying tensor fasciae latae and adjacent fat. The deep layer of fascia lata has been incised near the trochanter and the retinacular branch of the lateral femoral circumflex artery is visible in the window. Posteriorly, the arcuate tendinous fibers of the glutaeus maximus are retracted and a portion of the osseous insertion has been divided. Branches of the inferior gluteal vessels are not cut.

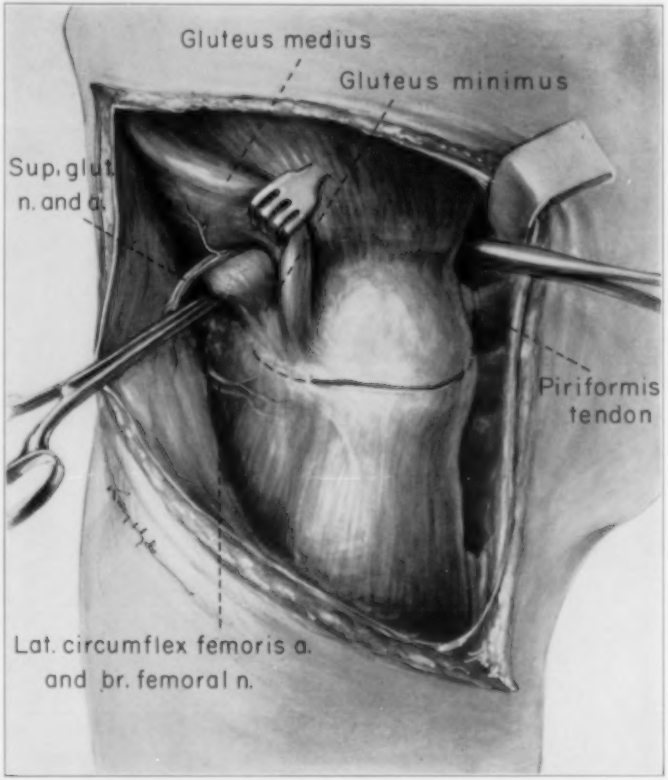
Gluteus medius
Gluteus minimus
Sup. glut. n. and a.
Piriformis tendon
Lat. circumflex femoris a. and br. femoral n.

Fig. 5

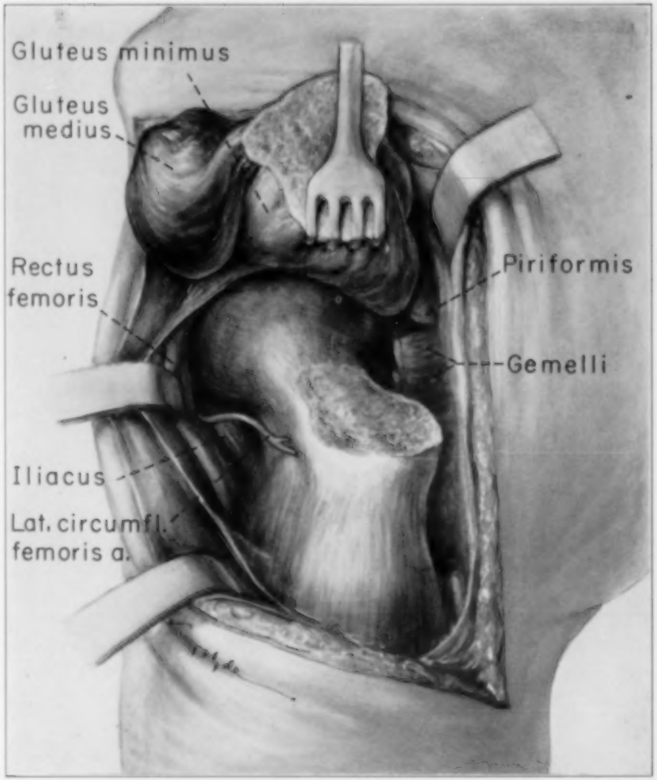
Gluteus minimus
Gluteus medius
Rectus femoris
Piriformis
Gemelli
Iliacus
Lat. circumfl. femoris a.

Fig. 6

Fig. 5: Isolation of the greater trochanter for osteotomy. The instruments have been inserted between the deep surface of the glutaeus minimus and the hip-joint capsule. The tendon of the piriformis has been divided.

Fig. 6: Completion of the anterior and superior aspects of muscle dissection. The deep retractor displaces the rectus medially, demonstrating the lateral border of the iliopsoas and the retinacular branch of the lateral femoral circumflex artery.

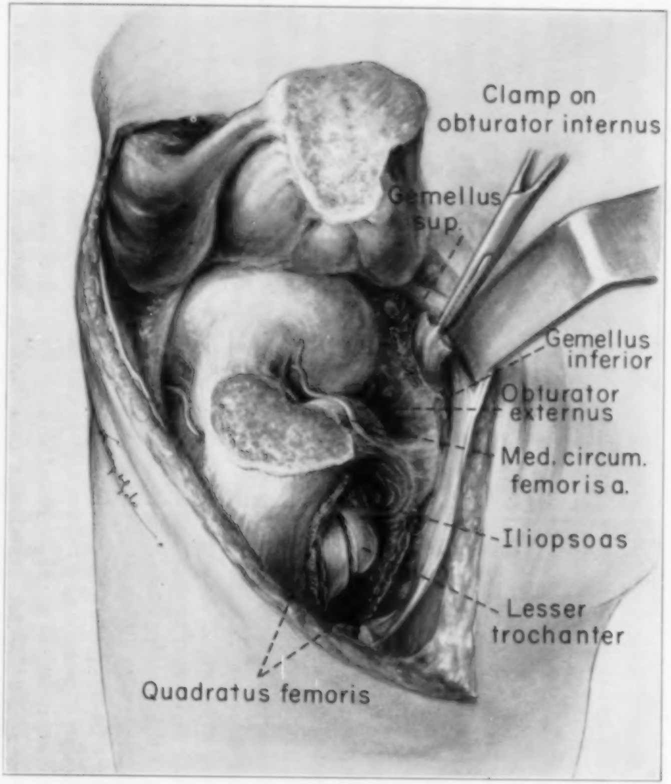
Clamp on obturator internus
Gemellus sup.
Gemellus inferior
Obturator externus
Med. circum. femoris a.
Iliopsoas
Lesser trochanter
Quadratus femoris

FIG. 7

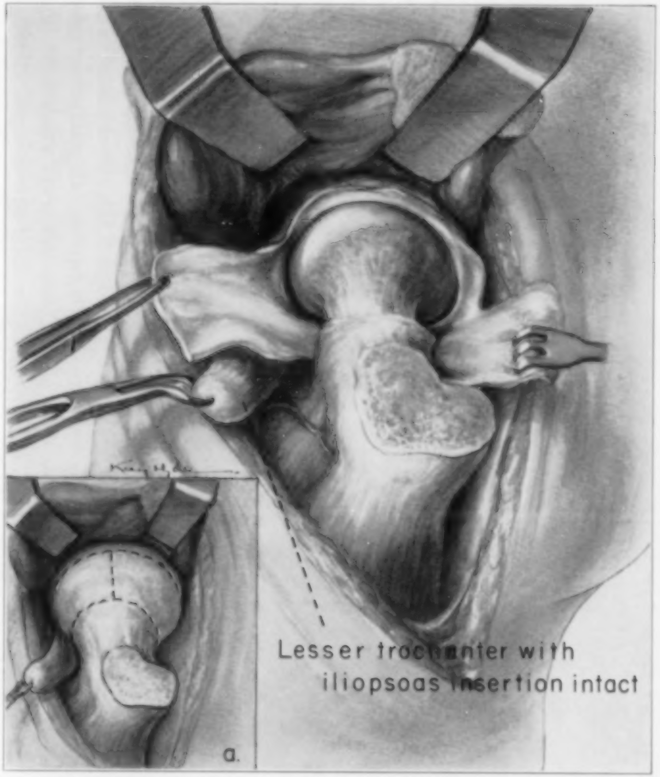
Lesser trochanter with iliopsoas insertion intact
a.

FIG. 8

Fig. 7: Muscle dissection, posterior aspect. The short external rotators have been tenotomized. The lesser trochanter has been osteotomized near its base. The retinacular branch of the medial femoral circumflex artery crosses the tendon of the obturator externus.

Fig. 8: Drawing showing the method of incision of the capsule when complete capsulectomy is indicated. The iliopsoas tendon with the attached lesser trochanter has been displaced anteriorly.

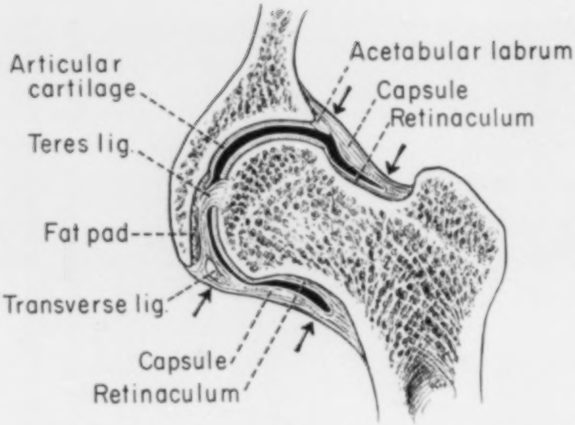

FIG. 9

Diagram of the mid-coronal section of the hip joint. The arrows indicate the approximate point of the capsular section to avoid injury to the retinacular vessels.

maximus and the short external rotators. Extension and internal rotation of the thigh aid the approach. The freed border of the glutaeus maximus which has been detached from its aponeurotic insertion is elevated, allowing identification of the arcuate tendinous fibers on its deep surface and their insertion into the gluteal tuberosity (Fig. 4). The tendinous fibers that compose the proximal portion of this osseous insertion are divided for a distance of about 3.0 centimeters, parallel to the femur and about 1.0 centimeter from it (Fig. 4). Careful division of only the tendinous fibers will prevent injury to terminal branches of the inferior gluteal artery found in the fatty tissue in the center of the tendon. The freed border of the glutaeus maximus can now be retracted posteriorly like a curtain, exposing the region of insertion of the short external rotators and, in addition, the lesser trochanter. The overlying areolar tissue and the tendons of the short external rotators are divided 0.5 centimeter from the bone, starting with the piriformis and continuing with the superior gemellus, obturator internus, inferior gemellus, and quadratus femoris. This allows exposure of the superior retinacular branch of the medial femoral circumflex artery, which lies deep to these tendons but superficial to the obturator externus (Fig. 7). Retraction of these short external rotators medially protects the sciatic nerve. The tendon of the obturator externus is cut near its insertion into the trochanteric fossa and is dissected from the posterior aspect of the capsule. Inferiorly, the retinacular branches of the medial femoral circumflex artery are found to emerge from the fat between the tendons of the iliopsoas muscle group and the belly of the obturator externus (Figs. 7 and 11). This important vascular supply to the head and neck of the femur is preserved. Protection can be afforded by retraction of the obturator externus medially and inferiorly away from the capsule. The posterior capsule of the hip joint is exposed.

Inferior portion: The most difficult part of the capsule to expose is the inferior portion. If fixed deformity exists in a marked degree, complete exposure of the inferior portion may be deferred until the remainder of the capsule has been sectioned and the femoral head has been dislocated (Fig. 10). When fixed adduction is caused by contracture in the region of the pubocapsular ligament, circumferential section of the inferior part of the capsule on the femoral side is generally necessary to accomplish dislocation of the femoral head without excessive trauma.

Complete exposure of the capsule inferiorly is accomplished by gradual extension of the anterior and posterior muscle dissections in an alternating fashion. When there is contracture of the iliopsoas muscle group, the exposure is facilitated by osteotomy of the lesser trochanter, which allows release of these muscles (Fig. 7). The region of the lesser trochanter has been exposed by tenotomy of the quadratus femoris. Exposure of the lesser trochanter is completed by dissection of the overlying areolar tissue. The lesser trochanter is osteotomized at its base and the remaining fibers of the iliacus inserting adjacent to the pectineal line are divided (Fig. 7). With the thigh in extension and internal rotation, the dissection proceeds close to the capsule. A retractor placed between the capsule and the obturator externus protects the medial circumflex vessels and their retinacular branches during the remainder of the inferior dissection from the posterior aspect.

Completion of the inferior exposure from the anterior aspect can be made easier by flexion, abduction, and external rotation of the thigh. The inferior portion of the capsule is separated from the iliopsoas muscle group. This allows the conjoined tendon of the iliopsoas with the attached fragment of the lesser trochanter to be pulled anteriorly (Fig. 8). Separation of the entire external surface of the capsule with its accessory ligaments from the overlying structures now is complete.

Incision or Resection of the Hip-Joint Capsule

This exposure allows incision or resection of any portion of the articular capsule. Partial circumferential incision of the capsule is generally sufficient to permit either anterior or posterior dislocation of the femoral head from the acetabulum (Figs. 10 and 11).

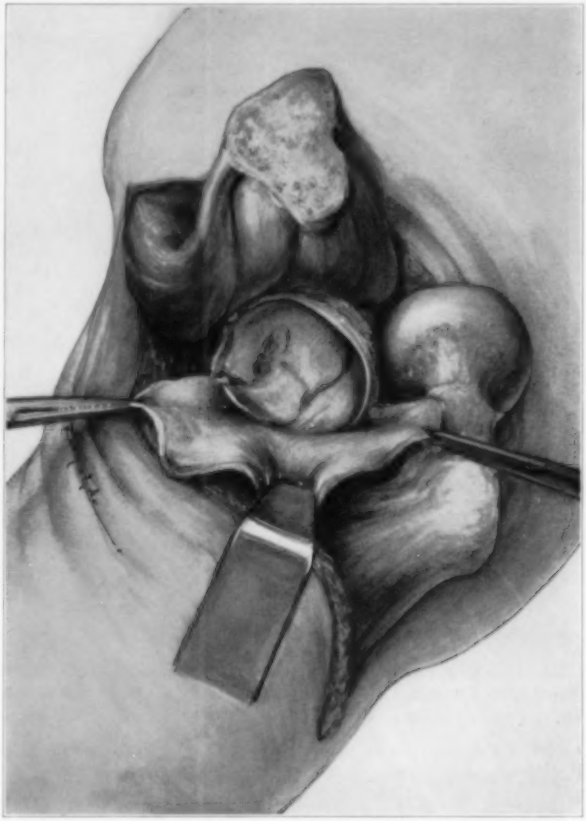

FIG. 10

Posterior dislocation of the femoral head. Division of the inferior portion of the capsule at the acetabulum can be deferred until after dislocation of the femoral head.

Complete excision of the articular capsule with the accessory ligaments can be accomplished in the following manner. The superior portion of the capsule is divided parallel to the neck of the femur between the acetabulum and the base of the greater trochanter (Fig. 8). Complete circumferential section on the acetabular side is made close to the glenoid lip and the transverse acetabular ligament; on the femoral side, at the junction of the capsule and the cervical retinacula (Fig. 9). The blood supply to the neck and head of the femur carried by the retinacula can be preserved by avoiding elevation of these structures from the underlying bone. Dislocation of the hip permits the entire acetabulum to be seen.

Closure of the Wound

The thigh is maintained in abduction during closure to facilitate attachment of the greater trochanter. The articular capsule can be sutured if excision is not desirable. Either the trochanters are attached in their anatomical positions or they are translocated (Fig. 12). Three sutures of 18-gauge stainless-steel wire are used for the greater trochanter, while one or two are sufficient for the lesser trochanter. The divided tendons of the short external

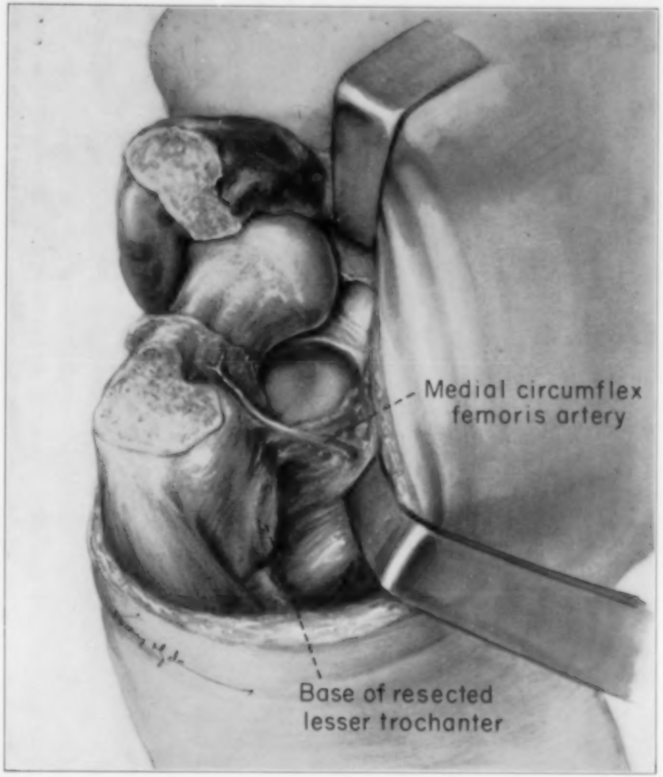
Medial circumflex femoris artery
Base of resected lesser trochanter

FIG. 11

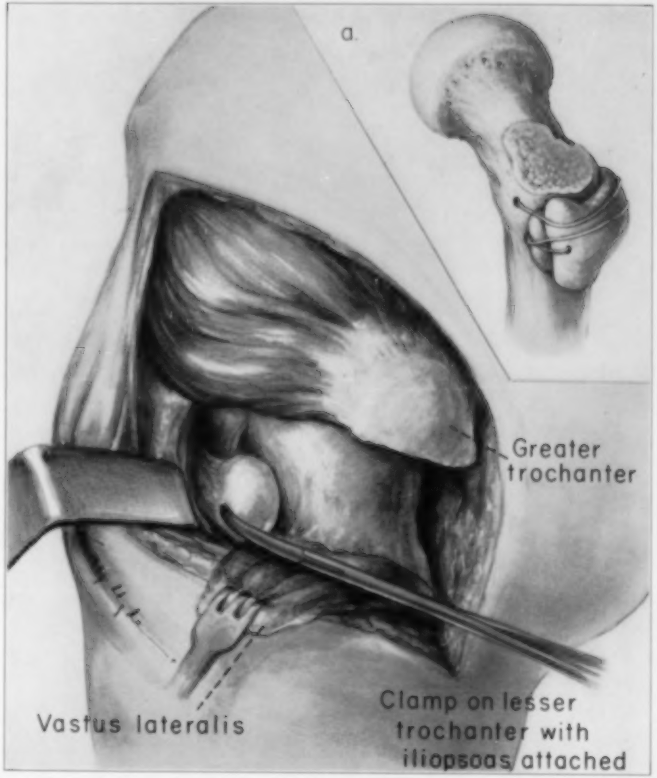
a.
Greater trochanter
Vastus lateralis
Clamp on lesser trochanter with iliopsoas attached

FIG. 12

Fig. 11: Anterior dislocation of the femoral head. The retinacular branches of the medial femoral circumflex artery are demonstrated.

Fig. 12: Translocation of the trochanters. The proximal end of the vastus lateralis has been reflected. The greater trochanter is attached distal and posterior to its normal location. The lesser trochanter has been translocated to the anterolateral aspect of the shaft below the oblique line. The insert (*a*) demonstrates a method of attachment.

rotators with the overlying areolar tissue are attached loosely. The partially divided osseous insertion of the glutaeus maximus is repaired. The remainder consists in simple closure of the deep and superficial fasciae and the skin. It is preferable to drain the wound for forty-eight hours.

POSTOPERATIVE CARE

The affected extremity is maintained in abduction, extension, and neutral rotation by balanced suspension. In order to assure constant abduction, a retentive sling is placed around the sound thigh and is anchored to the bed. Balanced suspension is discontinued when the wound is healed, generally ten to fourteen days after operation. Abduction is maintained for three weeks.

Partial weight-bearing may be initiated at the beginning of the fourth week if uncomplicated wound healing is the sole determining factor.

COMMENT

When extensive exposure of the region of the hip joint is necessary, this surgical approach provides access to the upper end of the femur, to all of the articular capsule, and to the entire external aspect of the acetabulum. In order to accomplish such exposure, extensive division of muscle insertions into the upper end of the femur is necessary. Obviously, this approach should be reserved for operative procedures that cannot be accomplished with less extensive dissection.

Limited surgical exposure frequently causes unnecessary trauma from retraction. Accidental fracture of the upper end of the femur may result from an attempt to dislocate the hip joint before restricting soft tissues are released. Adduction deformity is commonly associated with capsular contracture in the region of the pubocapsular ligament. Correction of such deformity may be totally or partially dependent upon the release of capsular contracture. In the absence of bony ankylosis, circumferential division of the capsule allows dislocation of the hip joint without preliminary osteotomy of the femoral head or acetabulum.

The most common use of this exposure has been for arthroplasty in cases of advanced hip-joint disease. Such reconstructive surgery necessitates extensive tissue exposure, with attendant loss of blood. It is preferable to correct this loss at the time of operation.

Attention to anatomical details will prevent injury to important blood vessels and nerves. The superior gluteal nerve is the single major nerve exposed. It is not necessary to expose the sciatic nerve. Careful retraction, the short external rotators being used as a cushion, affords protection to that nerve. The retinacular branches of the medial and lateral femoral circumflex arteries are the important vessels encountered. This component of the vascular supply to the upper end of the femur is preserved.

Osteotomy of the trochanters is preferred to tenotomy. The attached bone simplifies re-insertion of the tendons. Postoperatively, the fragment of trochanteric bone serves as a roentgenographic marker, indicating the competency of tendinous repair.

SUMMARY

A comprehensive exposure of the entire capsule of the hip joint, the acetabulum, and the upper end of the femur has been described. The operation can be performed without injury to important blood vessels or nerves. Extensive division of tendinous insertions into the upper end of the femur is necessary. This surgical approach is not simple and should be reserved for resection of the upper end of the femur, for arthrodesis, or for extensive reconstruction of the hip joint.

NOTE: The authors would like to express their appreciation to Prof. John B. deC. M. Saunders who provided the facilities of the Department of Anatomy for dissections and to Miss Kay Hyde who made the illustrations.

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DISCUSSION

Surgery of the Rheumatic Hand

(*Continued from page 766*)

opposite of the former. It is a state of contracture of the intrinsic muscles.

The central feature of Bunnell's paper is his new and startling method of overcoming the strong flexion contracture and the volar dislocation of the basal phalanges in the pill-roller type, and the extension contracture and dorsal dislocation in the claw-hand type of this deformity.

We agree fully with his principle of skeletal shortening to reduce the contracture and dislocations on the grounds that, in the face of myositic contracture with marked fibrosis, tendon lengthening or stripping of the muscle is of little avail. We have learned this lesson in the ischaemic contracture of Volkmann where a resection of the wrist or even the shortening of the forearm bones as advised by Spitzy, means more to the salvaging of muscle function than does any tendon or muscle surgery, provided, of course, that there is something to salvage. The point is only from which end is the metacarpal skeleton to be shortened, — distally by resection of the heads and arthroplasty, or proximally, as Dr. Bunnell now suggests, by removing the bases of the metacarpals.

By and large, the older method of resecting the heads has given acceptable results; in fact, the metacarpophalangeal joints are now counted as among those suitable for arthroplasty, but there are drawbacks. While mobility is satisfactory, stability of the newly made joints is not, and ulnar deviation, so typical of the arthritic pill-roller hand, inevitably develops.

As I understand it, the shortening of the metacarpals by resection of the bases is restricted to patients who as yet do not show a dorsal or volar over-riding of the dislocated basal phalanges. In this group of cases, the tightening of the joint by fibrous-tissue contracture with internal fixation by pin seems to me a basic point; furthermore, Dr. Bunnell overcomes the propensity to ulnar deviation, the "ulnar drift" as he calls it, by displacing the long extensor tendon radially, at least for the index and little fingers. There can certainly be no objection to this procedure, and it will mean an advance in the functional restoration of these pitifully crippled hands.

Why are they pitifully crippled? I note with satisfaction that Dr. Bunnell points out that these muscles are contracted from irritation first in the state of spasm and only later do they become structurally changed by progressive fibrosis.

A spastic muscle is an extensible muscle which has retained its elasticity; a fibrosed muscle has lost its elasticity. If we may draw a parallel with arthritic contractures in other joints, for instance the knee, we know that the arthritic muscle remains in its reflex spastic state for a long time and that correction by mechanical means and the restoration of balance by muscle educational means offer a wide opportunity to the more acute and subacute cases. Why, then, should the arthritic hand be an exception?

Dr. Bunnell emphasizes the necessity of early preventive treatment of arthritic contractures of the hand in stages where conservative methods are not only of avail, but where the results obtained are far superior to any operative achievement accomplished in later stages. This cannot be stressed enough. Today, when we can do so much for the control of rheumatic arthritis by anti-rheumatic drugs, for the prevention of contractures by interrupted and single-purpose splinting, for the re-education of imbalanced muscle by physiotherapy and muscle training, it is difficult for me to understand this indifferent and *laissez faire* attitude which is so commonly displayed toward this type of arthritic contractures.

NOTE: During the course of their experimental investigation of bone transplanting, Dr. Chase and Dr. Herndon very thoroughly reviewed the literature on that subject. Fortunately, they listed references and kept careful abstract and digest notes. From these summaries came the following article. Through it readers of *The Journal* wishing to keep abreast of progress or to become familiar with the accredited body of knowledge in this field may have the benefit of this thoroughgoing study of recorded contributions and achievements in this phase of tissue transplant.

The Editor

THE FATE OF AUTOGENOUS AND HOMOGENOUS BONE GRAFTS

A HISTORICAL REVIEW

BY SAMUEL W. CHASE, M.D., AND CHARLES H. HERNDON, M.D., CLEVELAND, OHIO

From the Department of Anatomy and the Department of Orthopaedic Surgery of the Western Reserve University School of Medicine and the University Hospitals of Cleveland, Cleveland

The recent increased interest in the clinical use of homogenous bone stimulated the authors not only to study experimentally the feasibility of massive homogenous bone transplantation but also to review the extensive literature related to the subject. Because this review has been extremely informative to the authors and because it is apparent from the recent literature that many of the older experiments are being repeated today, a brief summary of the material reviewed will be presented, together with a more complete bibliography.

Duhamel is generally accredited with the first scientific attack on the problem of osteogenesis. He placed silver wires subperiosteally and found, weeks later, that they were covered by bone. (This work was done in 1739 and was reported in 1742.) Duhamel believed that this new bone was produced through the osteogenic property of the periosteum. On the other hand, von Haller (1763) regarded the periosteum as being chiefly the support for blood vessels which were agents for osteogenesis in the healing of fractures and believed that osteogenesis was due to an exudation from arteries. Two sharply divided schools of belief arose, based on the views of these two men. Although Heine (1836) totally resected ribs subperiosteally and found that they grew back, the controversy was not settled until Flourens (1842) conclusively showed that periosteum is osteogenic and is the chief agent in the healing of bone defects.

The first really scientific approach to the problem was made by Ollier who, beginning in 1858, without benefit of modern histological techniques or aseptic surgery, carried out exhaustive studies on periosteum. In 1867 he reviewed the earlier literature, gave a full report on his experiments, and concluded that transplanted periosteum and bone remained alive and could under proper circumstances become osteogenic. He believed that viable bone with attached periosteum was the best form of graft to use, but that the contents of the Haversian canals and the endosteum were important in bone regeneration. His views were not seriously questioned until the numerous papers of Barth (1893 to 1898), a student of Marchand, appeared. Barth claimed that all transplanted bone, marrow, and periosteum die and are replaced by surrounding tissue. His work was based almost solely on replanted discs removed by trephine from the skull. Barth's work attracted a number of ardent supporters and, at the same time, there was stiff opposition to his views by others. Many polemical papers were written on each side to substantiate opposing views, particularly by Barth and by David at the close of the nineteenth century.

Axhausen made a major contribution to the problem of osteogenesis and bone transplantation when he reported (1907, 1909) on his exhaustive and scientifically planned experiments. On the basis of these experiments he formulated his well known principles that periosteum has in high degree the property of survival and osteogenic activity in autografts, markedly less in homografts, and practically none in heterografts. Axhausen's experimental work with rabbits and rats (1909) was substantiated by material from human sources (1911). He believed that all transplanted bone dies but that most of the periosteum survives and is a source of lively osteogenesis. He, therefore, gave first preference to periosteum-covered transplants for clinical use. These views have been substantiated by later investigators and are largely accepted today.

One contradictory argument was raised by Macewen (1912), who reported upon results of animal experimentation and reaffirmed his previous statement, made more or less dogmatically in 1887 based on clinical observations, that periosteum *per se* does not form bone but acts as a limiting membrane and serves as a source of nutrition to the bone. It would seem that the cause for the contradiction between Macewen and his followers (Davis and Hunnicutt, 1915; Hey Groves, 1913; Cohn and Mann, 1915; and others) and Axhausen was Macewen's failure to recognize the cambium layer as part of the periosteum. In 1908 even Barth, influenced by the findings of Grohé (1899), Saltykow (1900), Marchand (1901), Sultan (1902), Axhausen (1907), and Tomita (1907, 1908), retracted his original views and accepted Axhausen's principles almost verbatim.

Because Axhausen's fundamental principles have been adequately confirmed and have become accepted, later investigators have concerned themselves more with the contribution to the regeneration of a graft from the host bed than to the role played by the transplanted periosteum. The subject has become complicated, however, by the bitterly fought controversy between those who believe that bone can arise by metaplasia from the surrounding connective tissue and those who believe that it arises only from soft tissues associated with bone. This controversy even today is not adequately settled, but the proponents of the metaplasia theory are more numerous than the opponents.

Certain modern schools (Levander, 1934; Annersten, 1939; Lacroix, 1947; Hartley, Tanz, and Schneider, 1949), particularly in Sweden and Belgium because of the previous work of Nakahara and Dilger in 1909, Sasaki in 1911, and Jokoi in 1912, have been interested in studying the effect of injections of various emulsions and extracts of bone and periosteum in an attempt to isolate an organizer substance which would stimulate osteogenesis. Heinen, Dabbs, and Mason (1949), Ray, Degge, Gloyd, and Looney (1952), and others have been unable to confirm the presence of a specific chemical osteogenic organizer. Other investigators have approached this problem through the study of heterotopic bone formation. Many have demonstrated osteogenesis in the anterior chamber of the eye following various stimuli and, although it appears logical that an organizer substance is related to and may stimulate the formation of bone, there is as yet no definite proof that such a substance has been isolated.

Our present-day knowledge of the histological fate of bone following transplantation is but little changed from the views originally presented by Axhausen. Following a massive transfer of viable bone, the periosteum in great measure survives and retains its osteogenic capacity while most of the bone and marrow die. Articular cartilage and epiphyseal cartilage have a long period of survival but usually die, except for local regions which survive. Repair and reorganization are accomplished through the agency of vascular, fine-fibered connective tissue which invades from the periosteum of both host and graft, from the marrow of the host, and sometimes from the surrounding tissues of the host. By transformation this tissue becomes locally osteoclastic or osteoblastic, with subsequent reorganization of the spongiosa and compacta. This same tissue becomes converted to typical myeloid tissue or goes on to form a fatty type of marrow. All reorganization of bone, as was stated by Axhausen, is by resorption and apposition. Although the term "creeping substitution" has frequently been used to designate the mechanism of bone replacement, it is certain that, in this country at least, it has been erroneously used to describe a process which is really resorption and apposition. The term as originally used by Barth (1893, 1894) and Marchand (1899, 1901) signified a process of replacement by budlike masses of new bone invading the old without previous resorption of the old bone;

concomitantly the osteoblasts might wander through canaliculi to occupy empty lacunae. Neither Barth nor Marchand considered creeping substitution to be the sole method of replacement, admitting the occurrence of the usual method of resorption and apposition, but they felt that it was by far the more important process.

Following a massive homogenous viable bone graft, healing takes place by the same process as in autogenous grafts, but the rate of the healing process is slower. Revascularization in the homogenous grafts occurs as rapidly as in the autogenous transfers, but the process of resorption and apposition is much delayed.

The extensive investigations dealing with various forms of dead bone (boiled bone, os purum, decalcified bone, ashed bone, and frozen bone) have also shown that a similar process of repair occurs, but again there is a variation in the timing of the stages of repair. There has been marked contradiction in the claims of different authors. Some have claimed that various forms of dead bone may be reorganized even more rapidly than fresh autogenous bone, but the consensus is that all forms of dead bone, although they may be utilized by the host, do not show as rapid resorption and apposition as do fresh autogenous grafts. Many authors stress that the complete reorganization of dead bone may be delayed even for years. There is evidence to substantiate the claim that, of all forms of dead bone, frozen bone is most readily replaced. However, the recent investigations of Reynolds, Oliver, and Ramsey indicate that merthiolate-preserved bone is utilized as readily as frozen bone; and Kreuz, Hyatt, Turner, and Bassett have presented evidence to indicate that bone which has been frozen and dried is well tolerated by the host and is replaced as rapidly as frozen bone.

It is interesting to note that little difference has been observed between the timing of the healing process of viable homogenous-bone transfers and that of frozen homogenous grafts. Although the delay in the healing of homogenous-bone grafts (viable or dead) as compared with autogenous grafts is well recognized, this difference has not been proved so great that it has prevented interest in the use of homogenous bone clinically. Macewen is credited with having performed the first homogenous bone transplantation clinically in 1878. It was apparent, however, that the use of homogenous bone was not practical except in an occasional case, because usually it was not immediately available at the time it was needed for transplantation.

A paper by Grohé in 1899 was a milestone in that it established the fact that periosteum would survive refrigeration at 0 to 40 degrees centigrade for up to 100 hours and, following transplantation intramuscularly, exhibited osteogenesis. Morpurgo (1899) showed that not only could fowl periosteum be preserved at 3 to 6 degrees centigrade up to 192 hours, but it could also be kept in a moist chamber at 40 to 41 degrees centigrade up to 100 hours. He kept human periosteum at 15 degrees centigrade for up to 168 hours and showed that it formed cartilage and bone when transplanted into a host. Saltykow (1900) showed that the periosteum of rats still proliferated after preservation for fourteen days in agar or gelatine at 2 to 29 degrees centigrade.

Interest in devising methods of preserving and storing homogenous bone dates from the experimental work of Bauer in 1910, who showed that homogenous grafts could be preserved by refrigeration as long as three weeks and could then be successfully transplanted in dogs. Tuffier (1911) reported the successful clinical use of thin sections of bone refrigerated for as long as five days. Albee (1912) stored homogenous infant's bone in a refrigerator and used it later for bone-grafting purposes, and Smith (1937) reported two cases in which refrigerated homogenous grafts were used. Stimulated by the success of Inclán (1942) in preserving autogenous bone for varying periods of time by refrigeration, Bush and Wilson independently in 1947 developed the technique of preserving homogenous bone at −20 degrees centigrade in sealed containers. This technique proved to be a practical method of storing bone for varying periods of time, making it possible to have a ready supply of homogenous bone when needed for bone-grafting purposes. Other methods of storage have been investigated (storage in merthiolate solution; storage at room temperature after dessication of frozen bones), but so far the technique described by Bush and Wilson has proved to be the most practical for general use and is widely employed in orthopaedic centers throughout the country. Since the advent of the bone bank there have been many reports of case studies in which homogenous grafts preserved by storage at −20 degrees centigrade, in merthiolate solution, or by the freeze-dried technique have been used. The method of storage of homogenous bone apparently has not appreciably influenced the clinical result, as shown by comparable statistics presented by proponents of all three techniques of preservation. However, since there are so many other variables that must be taken into consideration, it is extremely difficult to compare the efficacy of homogenous-bone grafts with autogenous transfers when used clinically. From available reports it would appear that homogenous grafts used to reinforce spine fusions or other joint arthrodeses, to stimulate union in delayed union and non-union of fractures, and to fill bone defects give results roughly comparable to those in similar series of cases treated through the use of autogenous-bone grafts. It is evident, however, that, when massive bone replacements are carried out, such as replacement of part of a shaft of a bone or whole-joint transfers, the homogenous grafts are not as successful as the autogenous grafts.

Although there were a few pioneering attempts to use free bone grafts clinically during the nineteenth century, beginning with autogenous transfers by Philipp von Walther in 1820 and homogenous-bone grafts by Macewen in 1878, it was not until after the basic experimental work of Ollier (1862), Radzimowski (1881), Jakimowitsch (1881), Bonome (1885), Saltykow (1900), Sultan (1902), Axhausen (1907, 1909) and others that the transplantation of bone was performed in an increasing number of human patients. This work received its greatest impetus in the first two decades of the twentieth century and was stimulated, at least in part, by the clinical work of such investigators as von Bramann (1904), Tietze (1902), Müller (1900, 1903), von Mangoldt (1904), Tomita (1907), Lexer (1907), and Albee (1912, 1915). In the decade immediately preceding the twentieth century we found forty-five fairly well documented clinical reports of autoggenous-bone transplantations and ten of homogenous transfers, while in the first decade of the twentieth century we found 162 autogenous and twenty-nine homogenous transplantations. In the second decade there was a marked increase primarily in the autogenous transplantations; Albee alone reported over 1,600 successful autogenous transplantations (1919). Even in this early period the majority of the autogenous transfers were reported as successful. However, there is considerable difficulty in evaluating the results of most of the cases reported during this period. Since the early 1920's, bone-grafting has become so common that authors have often numbered their cases of bone transplantations in the hundreds and the emphasis has shifted from case reports to descriptions of different techniques used in bone-grafting.

Studies in whole-joint or half-joint transplantation were originally stimulated in 1901 by Tuffier, who reported a surgical replacement of the head of the humerus following a fracture-dislocation. He called this a chondroplastic resection.* This report was one of the stimuli that led Judet in 1906 to begin his experimental studies on half-joint and whole-joint transplantation, in which he used rabbits as experimental animals. He transplanted half joints and whole joints, both with and without the capsule, beneath the skin and sacrificed the rabbits at varying intervals to study the transfers histologically. He reported also two cases of homogenous knee-joint transplantations into physiological sites in rabbits with successful results. As a result of his studies Judet came to the conclusion that joint transplantation was more successful when the capsule was transplanted with the joint and that the best results were obtained if the capsule and the joint surface formed a physiological entity.

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* It is probable that Tuffier intended to use the French term *réfection*, meaning reconstruction, since he called his method *réfection chondroplastique* in the papers published in 1910 and 1911. Because attention was focused on the 1901 paper in which, possibly by editorial alteration or typographical error, *résection* was used, the technique has come to be known by the misleading name "chondroplastic resection".

Since Judet's original work, seven different experimental studies of whole-joint transfers have been reported. Five investigators used rabbits as experimental animals (Wrede, 1909; Impallomeni, 1911; Dalla Vedova, 1911; Pucci, 1913; Obata, 1914). Impallomeni transplanted whole autogenous and homogenous joints and Dalla Vedova transplanted whole homogenous joints, both with and without capsules, and came to the conclusion that it was a definite detriment to transfer the joint with the intact capsule, the result being superior when the capsule was excised. Pucci performed twenty-one homogenous whole-joint and half-joint elbow transfers, some direct and some after preservation from one to eight days at 0 degrees centigrade. Good results were reported in eighteen of these. Obata performed thirteen autogenous and thirty-two homogenous metatarsophalangeal-joint transfers and found vast superiority in the autogenous grafts: all of the homogenous transfers disintegrated. Impallomeni (1911) carried out eight whole-knee-joint transplantations in fowl with four good and four poor results, as well as four tibiometatarsal transplantations in fowl with only one successful result. Minoura (1914) reported on five different types of autogenous metatarsophalangeal-joint transplantations in young rabbits: (1) transplantation of whole joints; (2) transplantation of the distal half of joints; (3) transplantation of whole joints split lengthwise; (4) transplantation of the heads of metatarsals preserved in Ringer's solution for two, three, or four days; and (5) transplantation of homogenous whole joints. He performed 196 transplantations; 193 of these he followed for two months and two for 151 days. All of these transplantations were to soft tissues and none to physiological sites. On the basis of these experiments he concluded that autogenous transplants were superior to homogenous transplants. Herndon and Chase (1952, 1954) studied the fate of autogenous, delayed homogenous, and direct homogenous knee-joint transplantations in the dog; 129 transplantations were performed, but only fifty-six were satisfactory for detailed study. The animals were followed clinically and by x-rays. They were then sacrificed at intervals of from one day to two years and the grafts were studied histologically. Good functional results were obtained uniformly in the autogenous transplants; the grafts were rapidly revascularized and new bone replaced the dead bone in orderly fashion by resorption and apposition, the entire graft being reorganized within a period of nine months. In the homogenous transplants, regardless of whether the grafts were transplanted directly or had been preserved, the initial functional result was quite comparable to that in the autogenous transplants. After a period of four to six months, however, progressive degeneration of the joint appeared, with a concomitant limitation of function. The revascularization of the graft was almost as rapid as in the autogenous series, but there was a long delay in the appearance of resorption and new-bone formation. This process was not complete even after two years.

Although Tietze performed three human autogenous half-joint transplantations apparently successfully in 1902, Lexer was the first to perform a human whole-joint transplantation. He reported five homogenous whole-joint and four homogenous half-joint transfers in 1908 (the first operations were performed in November 1907). His whole-joint transplants consisted of four knees and one elbow, all having been obtained from fresh amputations. In one case, in which a knee joint was transplanted with a closed capsule, the procedure failed, the capsule becoming necrotic. In the case of the patient in whom the elbow transfer had been performed, he had no follow-up data after the fifth week. In the other three knee-joint transplantations he had good healing with excellent mobility in two and slight mobility in one. In two patients whom he followed for more than one year, regressive changes appeared between one and one-half and two years, but good function persisted. There was, however, extensive joint disintegration similar to that in arthritis deformans. Lexer subsequently reported eight additional homogenous whole-joint transplantations; he observed similar results in those cases in which the period of follow-up was long enough to observe the degenerative changes. Lexer stated (1925) that he had performed twenty-five whole-joint transplantations, although we found detailed reports on only thirteen, as recorded above. He claimed that he had obtained a permanent cure in twelve of the twenty-three transfers, consisting of nine knee joints and three finger joints. Of the nine patients with knee-joint transplantations reported as cured, two were followed for only eighteen months, six for "a few years", and one was not accounted for. Of the twelve patients with permanent cures reported, he admitted that regressive changes subsequently developed in two.

Bürkle-de la Camp (1929) made histological observations on two of Lexer's whole-knee-joint transplantations fourteen and sixteen years after operation, respectively. Lexer had claimed good functional results even though the roentgenograms showed extensive degenerative changes. Bürkle-de la Camp found histologically that the articular space had been maintained and that fibrocartilage had replaced the destroyed articular cartilages. All tissues were viable. Aside from a few remnants of cruciate ligaments and popliteal scar tissue, the intra-articular ligaments and menisci had disappeared; a form of capsule had developed. There were extensive marginal ridges and bony deposits in the articular capsule. (One of these patients had walked three kilometers daily to and from work.)

Buchmann (1908), using the closed-joint technique, substituted an autogenous first metatarsophalangeal joint for the elbow joint in two different cases. He reported good results, but Tuffier (1911) wrote that the functional result in both of these cases was imperfect. Unsuccessful attempts to transplant homogenous whole joints were made by Vaughan (1911), McWilliams (1912), Borst (1912), and Deutschländer (1914). Successful results were obtained by Duval (1913, cited by Tuffier 1913) when he replaced an elbow joint with a tibiotarsal joint. Eloesser (1913) replaced the fifth metatarsophalangeal joint with a similar joint from a cadaver. There was no follow-up report. R. Goebell (1913), McKeever (1945 but reported in 1952), and others have reported successful autogenous whole-joint transfers in the hand.

Half-joint transplantations have generally been more successful than whole-joint transfers. Lexer reported a total of eleven half-joint transplantations (including the four cases reported in 1908) and claimed that the transplants were well retained in all. Function, motion, and weight-bearing were well preserved. From a study of the details of Lexer's reports it would appear that these transplantations were fairly successful as a rule, although the periods of follow-up were too short in most cases for thorough evaluation. In spite of such favorable reports by Lexer and others, the results apparently were not impressive enough to justify popularization of the procedure.

Less extensive articular transplantations, such as Tuffier's chondroplastic resection, were more successful than whole-joint or half-joint transplantations. In this procedure the articular cartilage was transplanted, usually with the subchondral bone, as a covering of the bone ends in joint reconstruction. Tuffier reported replantation of the head of the humerus with its articular surface in 1901. In 1910 and 1911 he reported two chondroplastic reconstructions of the elbow joint. In 1913 he reported replacement of the articular surfaces of an ankylosed tuberculous elbow by the articular cartilage and subchondral bone from a tibiotarsal joint obtained from an amputation. Somewhat similar procedures have been carried out by Franz König and by Enderlen and Schmidt (1914). The cartilaginous-cup arthroplasty in ununited fractures of the neck of the femur as described by John Royal Moore in 1948 is in reality a similar procedure. He reported nine excellent results, one fair, and one poor result in cases of non-union of the neck of the femur treated by removal of the head of the femur, reaming of the cancellous bone down to the subchondral bone, and replacement of this cartilaginous cap over the reshaped trochanteric area.

It is apparent that in a review of this type it is impossible to present more than an account of the trends research has taken in the study of the fate of bone grafts. The authors wish to emphasize that they have in their files over 1,500 references which relate to this subject. Of this vast material, those references which we feel make a definite contribution to the problem have been included in the bibliography. Much of the earlier experimental work has not received the attention its deserves and it is hoped that, when the references to this material are provided, investigators will avoid reduplication of effort and devote their energies to the many problems which still remain unsolved. The authors believe that one of the greatest of these is the unknown specific factor in bone which produces the difference in behavior of homogenous as compared with autogenous bone.

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PROTEIN-BOUND IODINE IN LEGG-CALVÉ-PERTHES DISEASE

BY JACOB F. KATZ, M.D., NEW YORK, N. Y.

From the Blythedale Orthopaedic Hospital and Rehabilitation Center for Children, Valhalla, New York

Legg-Calvé-Perthes disease has been recognized as a clinical entity ever since the classical descriptions, independently, by the American Arthur T. Legg, in 1909, and by the Frenchman Jacques Calvé and the German Georg Perthes in 1910. Although the basis of the affection has been conceded to be a primary avascular necrosis of the epiphysis of the femoral head of either or both hips in children[9], little else of definitive etiology has been discovered despite considerable investigative efforts on the part of many workers.

The original instances of this disorder had been separated from large reservoirs of patients with juvenile hip tuberculosis. Since 1910, rickets, non-specific inflammation, trauma, hormonal imbalance, hereditary conditioning, and constitutional deficiency have been considered as potential or probable causative factors, singly or additively.

One of the more attractive theories, hormonal imbalance, was championed in 1936 by Cavanaugh, Shelton, and Sutherland when they presented five cases of osteochondritis of the capital femoral epiphysis in which metabolic deficiency was demonstrated; and they described the restoration to normal of the epiphysis after thyroid therapy. In 1941, Schaefer and Purcell elaborated on the theory of hormonal imbalance and stated that "juvenile chondro-epiphysitis" was due to hypothyroidism for which thyroid therapy was the treatment of choice.

In 1943, Gill presented his study of twenty cases of Legg-Perthes disease; he failed to find evidence of hypothyroidism in his patients. In discussing Gill's paper, Key said that there had been no improvement in his patients treated with thyroid hormone.

There the matter lay until 1954, when Emerick, Holly, Joistad, and Corrigan, writing on the diagnostic use of radio-active isotopes, stated that, in a study of twenty-eight children or infants, seven with Legg-Perthes disease had either thyroid hypofunction or toxic adenoma. In a recently released monograph on the Legg-Calvé-Perthes syndrome, Goff, while commenting on thyroid deficiencies, stated that one variety of the syndrome may yet be proved to be a subclinical athyroid manifestation.

Because of this renewed interest, cases of Legg-Perthes disease under treatment at Blythedale were reviewed. Because new investigative tools in thyroid study had been developed since Gill's work, it was deemed profitable to apply them in a re-examination of this perennial problem. Tracer studies with radio-active iodine, such as those reported by Emerick and his co-workers, were considered. However, after consultation with workers in that field, some skepticism was expressed as to the reliable range of radio-active tracers in the obvious subclinical group upon which the study was proposed. It was suggested that a safer and more dependable procedure would be to determine the level of serum protein-bound iodine.

Danowski and his associates[3] showed the constancy of protein-bound iodine in healthy adults. Starr had found the determination of protein-bound iodine to be reliable and diagnostic as a routine procedure and to be uninfluenced by limited exercise, food, or a forty-eight-hour delay in analysis. Standard levels of protein-bound iodine in infants to one year of age and in children from three to thirteen years had been recorded. Four to eight micrograms of protein-bound iodine per 100 cubic centimeters of serum or plasma for normal men, women, and children represented the accepted range. It was believed that protein-bound iodine is a reflection of the amount of the circulating thyroid hormone and, therefore, an objective index of thyroid activity. Serum cholesterol determinations

TABLE I

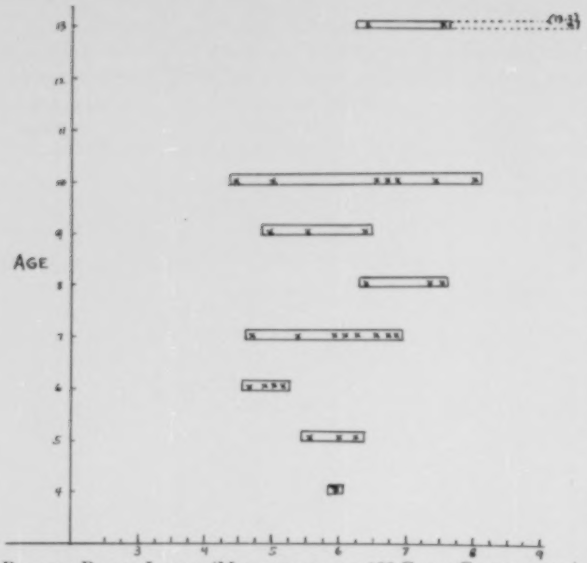
Serum Protein-Bound-Iodine Determinations In Thirty-Two Cases Of Legg-Perthes Disease

Case No.	Patient	Sex	Age (*Years*)	Hip Involved	Protein-Bound Iodine (*Micrograms per 100)*	Cholesterol (*Milligrams per 100)*
1	M.D.	F	4	L	6.0	314
2	S.M.	M	5	R	5.9	248
3	J.G.	M	5	L	6.2	319
4	H.J.	M	5½	L	5.5	260
5	J.M.	M	6	L	5.1	229
6	J.D.	M	6¼	R	4.6	203
7	V.B.	M	6¼	R	5.0	214
8	J.C.	M	6½	L	4.8	204
9	M.G.	M	7	L	5.3	241
10	L.I.	M	7	R	6.2	187
11	M.M.	M	7	R	5.8	225
12	L.G.	M	7	L	6.5	237
13	K.W.	M	7¼	R	4.6	194
14	J.S.	M	7½	R	6.7	194
15	A.O.	M	7½	L	6.8	193
16	D.C.	F	7½	R	6.0	168
17	M.L.	M	8	L	6.3	132
18	J.H.	M	8¼	R	7.3	203
19	R.C.	M	8½	R	7.5	234
20	A.L.	M	9	R	5.4	241
21	W.B.	M	9	Bilat.	4.9	211
22	R.P.	M	9½	L	6.3	290
23	W.W.	M	10	L	8.0	125
24	W.M.	M	10	Bilat.	5.0	130
25	J.G.	M	10	R	6.8	216
26	L.B.	M	10	L	6.7	188
27	D.B.	M	10	Bilat.	6.5	243
28	G.S.	M	10	L	4.4	258
29	H.B.	M	10½	R	7.4	199
30	A.S.	M	13	L	13.2	184
31	S.R.	M	13½	Bilat.	6.3	144
32	O.M.	M	13½	R	7.5	177

were also done on a blood specimen drawn at the same time in order to study its correlation to protein-bound iodine. Serum cholesterol has been regarded as an inconstant indicator of thyroid function.

Thirty-two children with Legg-Perthes disease, at present under treatment at Blythedale, formed the basis of the study (Table I). There were no instances of the clinical stigmata of hypothyroidism (dullness, skin or hair changes, and epiphyseal dysgenesis). The ages ranged from three to thirteen years; twenty-five (78 per cent.) of the children were in the age group of six to ten years. Thirty were males and two were females.

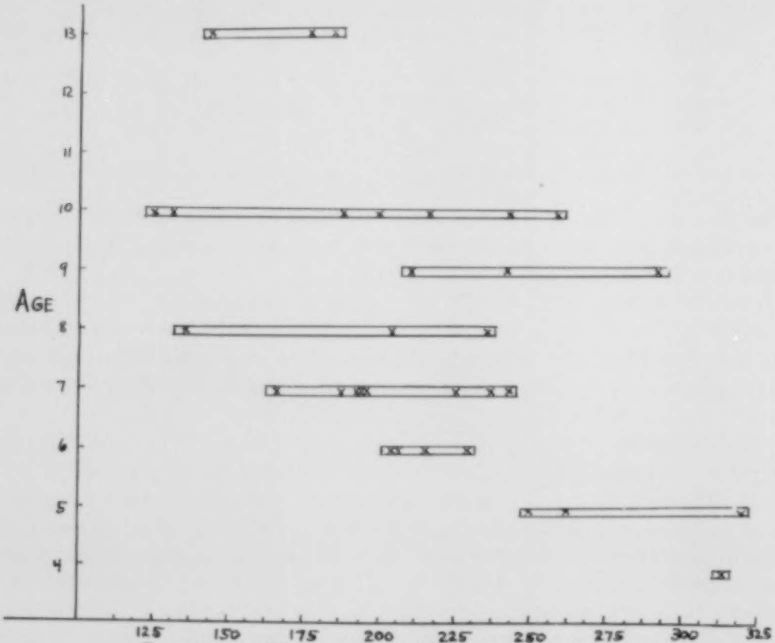
An analysis of the results revealed (Chart I) that thirty-one of the thirty-two protein-bound-iodine determinations fell within the range of 4.4 to eight micrograms per 100 cubic centimeters of serum. In one patient, thirteen years of age, without obvious constitutional basis and in whom one hip was involved in a severe Perthes process, the level was 13.2 micrograms per 100 cubic centimeters of serum. There were no recordings in the range one to three micrograms per 100 cubic centimeters of serum which had been described for hypothyroidism. There was no correlation of the protein-bound-iodine levels with any age group, site of the lesion, or whether the disease process was unilateral or bilateral. Talbot reported on thirty-nine normal children in whom he had found a range of protein-bound



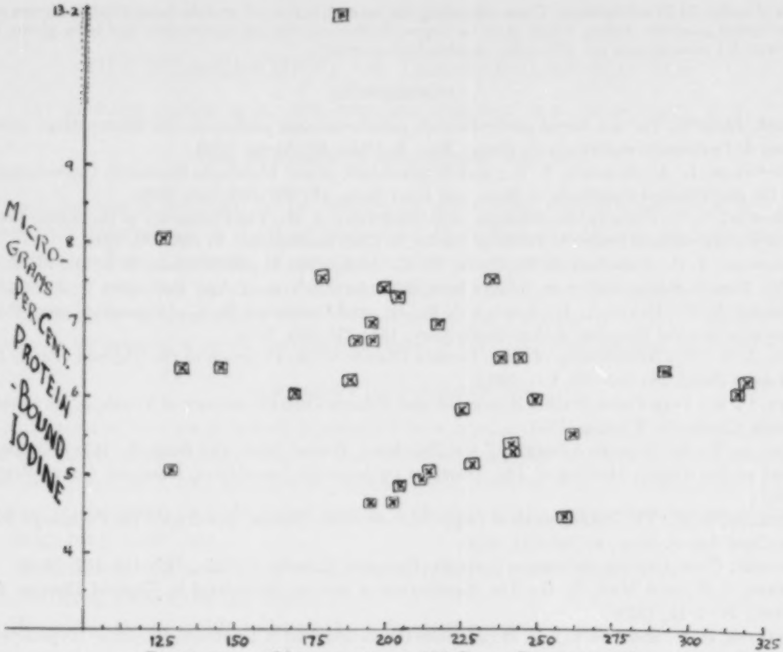
Protein-Bound Iodine (Micrograms per 100 Cubic Centimeters).
Chart I

iodine from four to seven micrograms per 100 cubic centimeters of serum with an average of 5.5 micrograms per 100 cubic centimeters of serum. The average in this study, including all determinations, was 6.3 micrograms per 100 cubic centimeters of serum.

Cholesterol determinations were made on blood samples drawn at the same time. Examination of the results of this study (Chart II) showed a wide range of readings from a low of 125 milligrams per 100 cubic centimeters of blood to a high of 319 milligrams per 100 cubic centimeters of blood. The greatest number of patients, twenty-three (72 per cent.), fell within 150 to 250 milligrams per 100 cubic centimeters of blood. Wilkins had shown that serum cholesterol of normal children varied from ninety-eight to 308 milligrams per 100 cubic centimeters of blood. He also stated that, although untreated hypothyroid children frequently showed higher concentrations of cholesterol, there were some patients with severe hypothyroidism with cholesterol determinations within the normal range. Peters



Cholesterol (Milligrams per 100 Cubic Centimeters).
Chart II



CHOLESTEROL (MILLIGRAMS PER 100 CUBIC CENTIMETERS).

CHART III

and Man concluded that in border-line cases of hypothyroidism the "concentrations of cholesterol in the serum appear to be quite capricious".

Finally the data were examined (Chart III) to determine whether correlation existed between the protein-bound-iodine and cholesterol levels. There was wide dispersal of cholesterol readings at all levels of protein-bound iodine with no correlation. In frank hypothyroidism, Peters and Man found significant grouping of high cholesterol with low protein-bound iodine, but this relationship did not invariably follow. The scattered recordings of cholesterol at all levels of protein-bound iodine seen in our patients followed the pattern of the normal levels recorded by Peters and Man.

SUMMARY

Thirty-two cases of Legg-Calvé-Perthes disease currently under treatment at Blythedale were studied in order to learn whether protein-bound-iodine determinations would clarify further the often suspected hypothyroid basis of Legg-Perthes disease. The level of serum protein-bound iodine has been found to be a reliable index of thyroid activity. The usual range of protein-bound iodine from four to eight micrograms per 100 cubic centimeters of serum was duplicated in thirty-one of the thirty-two patients here studied in whom a range of 4.4 to eight micrograms per 100 cubic centimeters of serum was found. One variation occurred at a level of 13.2 micrograms per 100 cubic centimeters of serum. There were no recordings in the hypothyroid range.

As an auxiliary study, blood cholesterol determinations were also made. No correlation, either with age or with the level of blood protein-bound iodine, existed. This failure of correlation, however, is not significant, since considerable variability under a variety of conditions is the experience reported in the literature.

NOTE: Since this paper was submitted for publication, additional information has been obtained relative to the sole instance of elevated protein-bound iodine. It was found that the patient had received two multivitamin capsules daily for the six months prior to his admission. Each capsule contained minor but significant amounts of iodine (0.33 milligrams). Upon repeating the determination of protein-bound iodine eleven months after the initial analysis, during which time no known iodine-containing medication had been given, the recording was 4.4 micrograms per 100 cubic centimeters of serum.

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DISCUSSION

Recurrent Dislocation of the Shoulder

(Continued from page 741)

Col. Brav (closing): In the first place, I do not think one should establish a 10 per cent. recurrence rate from two patients. I do not think such statistics have significance. If we had had 190 patients with twenty recurrences, that would be different. In the second place, as far as a two-year follow-up is concerned, I wrote to many people and asked about that. Most people, James Dickson, for example, and Osmond-Clarke, thought that practically all recurrences would take place in the first two years after operation, so that I felt safe in giving a two-year report.

Concerning re-operations, I have not operated upon these patients a second time. Most of them are out of the Service, and I do not know whether they would want another operation. If I had to choose, and with all due respect to Dr. Magnuson and Dr. Rowe, I think I would do a Bankart operation as a secondary procedure. There are recurrences with the Bankart and with the Magnuson-Stack operations, please remember that. I have seen them, even if Dr. Rowe and Dr. Magnuson have not. I am not advocating the Putti-Platt procedure or the simplified version of it above all others. We will have to see in the years to come just how successful it is. I think that the Magnuson-Stack, the Bankart, and the Putti-Platt procedures are *all* based on sound principles and are simply different methods of accomplishing our purpose.

I would like to pay a small tribute to my friend and teacher, Dr. Bruce Gill, who was one of the founders of the Academy and who has made so many noteworthy contributions to orthopaedic surgery. Among them he has written words to this effect: In the teaching of orthopaedic surgery (and, after all, that is our basic purpose) avoid methods and concentrate on principles. A mind that can grasp principles will devise its own methods.

THE MEASUREMENT OF TIBIOFIBULAR TORSION

BY HOWARD ROSEN, M.D., AND HERBERT SANDICK, M.D., NEW YORK, N. Y.

From the Hospital for Joint Diseases, New York

Tibial torsion is assumed to be frequently associated with a number of congenital and acquired deformities of the foot and knee. In certain conditions, such as club-foot, genu varum, and genu valgum, it appears to play an important role.

Treatment requires an exact determination of the degree of axial torsion, but the known methods of measurement have not proved to be sufficiently exact. The purpose of this study is to present a more accurate procedure for the measurement of tibial torsion.

DISCUSSION OF TERMINOLOGY

Tibial torsion is a term which is applied to a change in the axial relationship of the foot to the thigh. This change may be due to either rotation or torsion. Rotation may be defined as a turning of one unit about another unit; torsion may be defined as a twisting in the axis of the same unit. In other words, a change in the axial relationship of the foot to the thigh may occur by:

1. Rotation at the knee joint of the leg in relation to the thigh;
2. Twisting within the leg itself;
3. Rotation at the ankle joint of the foot on the leg.

Within the leg itself, several varieties of torsion or rotation may be considered. The fibula may rotate about the tibia, either at the upper or the lower end, or both (fibular rotation); the tibia can, theoretically, rotate about the fibula (tibial rotation). On the other hand, either of the bones may twist within itself (tibial torsion or fibular torsion). If the twisting occurs in both bones as a unit, the term "tibiofibular torsion" is used. It is difficult to determine by any method which of these factors is primarily responsible for the deformity. In view of actual difficulties in isolating the factors clinically or roentgenographically, and since all of the factors affect the tibiofibular unit, the term "tibiofibular torsion" is suggested and is used to describe any twisting within the leg.

METHODS OF MEASUREMENT

The methods of measurement[3] in use today are three in number: clinical, tropometric, and roentgenographic.

The most commonly used of these methods is the clinical method of inspection and palpation. The patient is usually placed in the sitting position, the patella and tibial tubercle pointing forward, with the legs dangling. The position of the malleoli is determined by palpation, and the line joining these is estimated. The degree of tibial torsion is judged by the angle which this line makes with the frontal plane. At times, the long axis of the foot is used as a guide to the line joining the malleoli or to the transverse axis of the ankle joint. These methods of clinical measurement are only approximate, for they are subject to the variations which may exist in the positions of the patella, the tibial tubercle, and the foot; they are also subject to the inaccuracies of clinical estimation.

The tropometric method, a somewhat more accurate method, has been most frequently used in anatomical specimens. Dupuis, however, uses this method in the living patient, as well as in the cadaver. The tropometer used by Dupuis is an instrument which combines a caliper to encompass the malleoli with a protractor for the measurement of the angle which the caliper makes with the horizontal. For measurement, the patient is placed with the leg horizontal and the patella pointing upward. Its accuracy is limited by variations in the position of the patella, the superior point of reference, and by the difficulty encountered in placing the tropometer accurately on definite points at the malleoli.

The roentgenographic methods are two in number. The first uses the conventional anteroposterior and lateral roentgenograms of the leg. A comparison of the upper and lower ends of the tibia and fibula in these roentgenograms gives a rough estimate of the tibial torsion[4]. The second method is that of Hutter and Scott in which the medial border of the foot is used as a reference line; this is related to the line of the malleoli on an anteroposterior roentgenogram of the foot. The objection to the latter method is that the medial border of the foot bears no constant relationship to the transverse axis of the ankle joint. In such conditions as metatarsus adductus and club-foot, this reference line may vary considerably.

DETERMINATION OF TORSIONAL AXES

The torsion between the upper and lower ends of the tibiofibular unit is measured by the determination of the angular relationship of a line drawn between two points in the proximal ends of the bones with a line drawn between two points in the distal ends of the bones. Thus, there is need to determine four fixed points. The choice of the two pairs of points is arbitrary, but the points must be constant. The following four points were chosen because of their more definite anatomical basis and because of the ease of their recognition both clinically and roentgenographically. The four points, as illustrated in Figure 1, are:

1. The upper lateral (*UL*)—the prominent junction of the anterior and lateral aspects of the distal part of the head of the fibula. Normally, a cross section made through the upper end of the fibula and tibia at the level of the head of the fibula shows the fibula and tibia each to be roughly quadrangular. The fibula has an anterior, a posterior, a lateral, and a medial margin. The interosseous margin is the medial margin. The point *UL* is seen to be at the junction of the short anterior margin with the longer lateral margin.

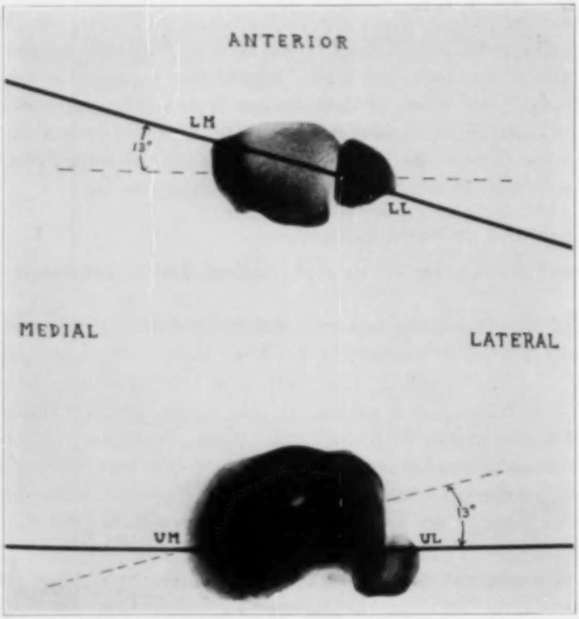

Fig. 1

Roentgenograms of a cross section through the upper and lower ends of an adult right tibiofibular unit. A wire is shown connecting the upper reference points *UL* and *UM*. Similarly, another wire connects the lower points *LL* and *LM*. The transcondylar and transmalleolar axes are marked by broken lines.

2. The upper medial (*UM*)—the prominent most medial point of the medial condyle which is the junction of the transcondylar line and the margin of the medial condyle of the tibia. The tibia, in cross section at this level, has longer anterior and posterior margins and shorter medial and lateral margins. The medial margin is convex, and its most prominent point is *UM*. This point can be identified clinically by its situation at the junction of the proximal end of the medial border of the tibia with the tibial condyle. The line connecting these two points (*UL* and *UM*) does not correspond

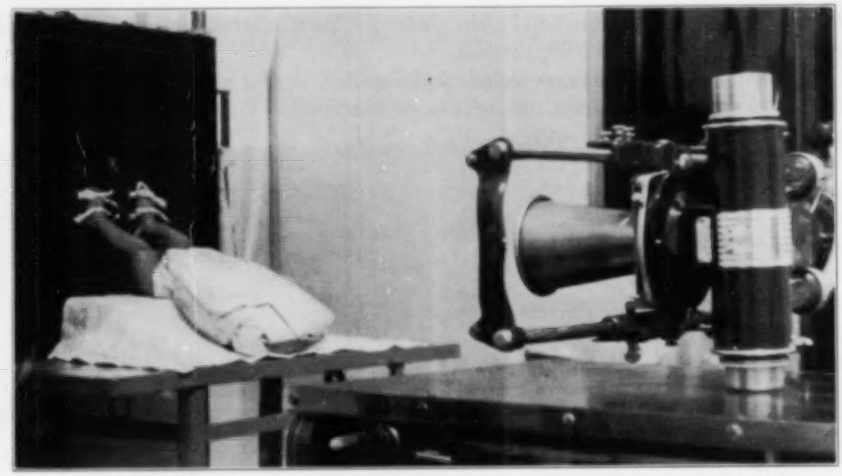

FIG. 2

Photograph illustrates the supine position used in making the standard 15-to-30-degree anterior-projection roentgenogram.

to the transcondylar axis of the tibia, but is approximately 13 degrees from it in the direction of lateral torsion.

3. The lower lateral (*LL*)—the prominence of the junction of the lateral and posterior margins of the lateral malleolus. It is seen on cross section that the lateral malleolus presents a triangular configuration. The interosseous or medial border of the lateral malleolus faces the interosseous border of the tibia and is in intimate contact with it. The remaining two prominent borders are the lateral somewhat curved border and the posterior border which is shorter than the lateral border. The junction of these is point *LL*.

4. The lower medial (*LM*)—the prominence of the junction of the anterior and medial margins of the medial malleolus. In cross section, the lower end of the tibia is quadrangular with an interosseous or lateral border, a long anterior border, and a shorter medial border; the posterior border is more or less parallel with the anterior border. Point *LM* is the junction of the long anterior border with the shorter medial border. The line joining the two points *LL* and *LM* does not correspond to the transmalleolar axis, but it is approximately 13 degrees from it, in the direction of lateral torsion. Thus, it is seen that the superior and inferior lines deviate to the same degree from the transcondylar and transmalleolar axes, respectively. Therefore, the torsion measured by means of these axes is the same as if it were measured by the use of the transcondylar and transmalleolar axes.

With the use of these four palpable points, an estimate of the degree of tibiofibular torsion may be gained clinically; however, a more accurate and graphic measurement can be obtained roentgenographically.

ROENTGENOGRAPHIC TECHNIQUE

The roentgenographic measurement of tibiofibular torsion resolves itself into a projection on a roentgenogram, without angular distortion, of one line joining the upper tibiofibular points and of another line joining the lower tibiofibular points. This might be accomplished by superimposing the upper end of the tibiofibular unit over the lower end and by projecting the rays longitudinally through the bones in this position. This is termed the superimposed or axial view (Fig. 6). However, it was found, when this projection was attempted, that the density of the bones precluded clear visualization of the four points. In the earlier phases of the study we had attempted to visualize these points in the axial view by the use of various opaque skin markers in the living subject. Because of the difficulty of accurate placement and maintainance of the markers over the reference points, this method was found to be impractical.

In order to eliminate these technical difficulties, it was necessary that the leg be extended 15 to 30 degrees from the right angle as shown in Figure 2. By this means, the lower end of the tibiofibular unit is moved anterior to the upper end in the sagittal plane (Fig. 6). By aiming the x-ray tube at the center of the legs, a 15-to-30-degree anterior-oblique projection of the leg is recorded on the film. It was found that, if the 30-degree limit has not been exceeded, the error resulting from this anterior projection is negligible. Similarly, it was found that the same limit applies to deviations in the frontal plane, that is, valgus or varus deviations.

In order to obtain this roentgenographic projection, the pa-

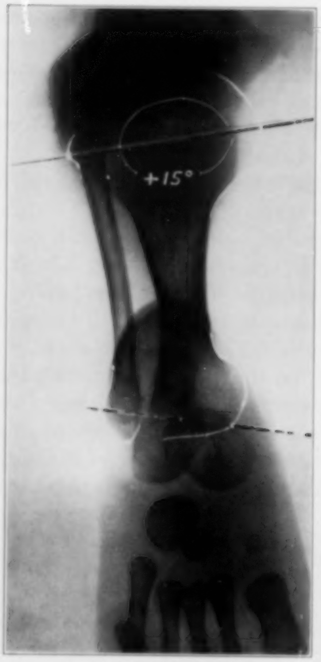

FIG. 3-A

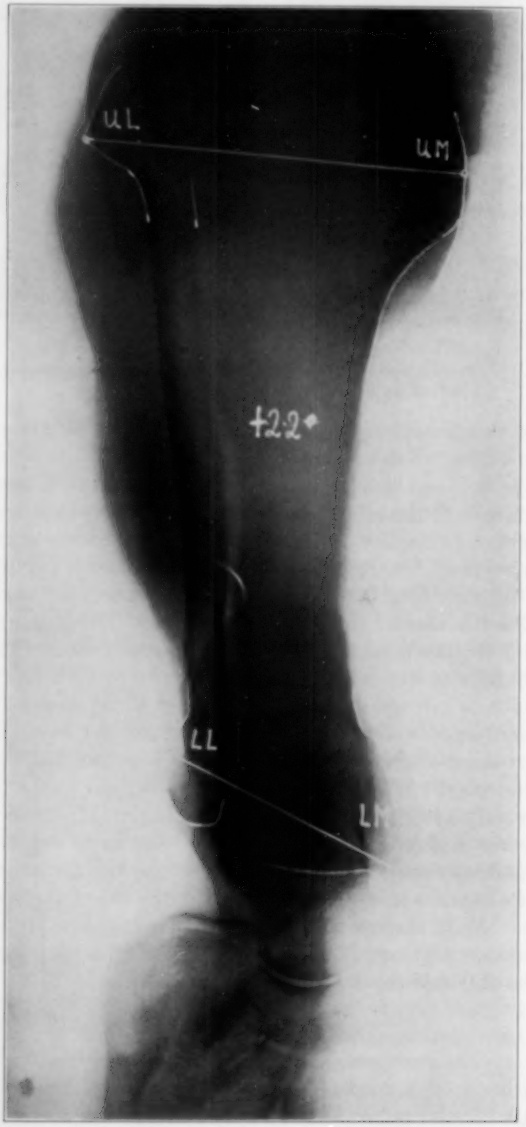

FIG. 3-B

Fig. 3-A: Typical roentgenogram demonstrating tibiofibular torsion in a child; there was 15 degrees of lateral torsion, which is within normal limits. When the upper tibial epiphyseal ossification center is present, it may be used as a guide to the point *UM* by bisecting the ossification center transversely and by extending this line medially to its intersection with the medial border of the medial condyle of the tibia.

Fig. 3-B: Typical roentgenogram demonstrating tibiofibular torsion in an adult; there was 22 degrees of lateral torsion, which is within normal limits.

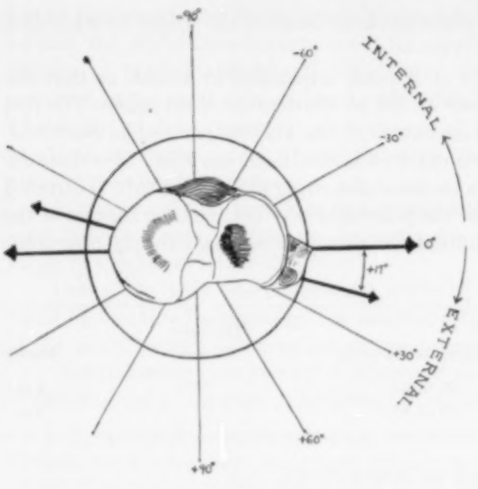
-90°
-60°
-30°
0°
+17°
+30°
+60°
+90°
INTERNAL
EXTERNAL

Fig. 4

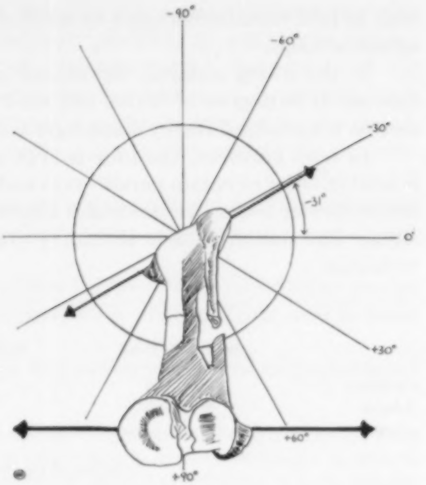
-90°
-60°
-30°
-31°
0°
+30°
+60°
+90°

Fig. 5

Fig. 4: Drawing of an adult right tibiofibular unit as seen from the tube of the x-ray machine in position for making the superimposed view. Wires cross the reference points and form an angle of +17 degrees of lateral torsion.

Fig. 5: Drawing of an osteotomized adult right tibiofibular specimen positioned for the making of a 15-to-30-degree anterior-projection roentgenogram as seen from the tube of the x-ray machine. There was −31 degrees of medial torsion in this specimen.

tient is placed either in the supine position or in the sitting position (the supine position is preferable for children). The patient is placed supine on the table with his hips at 90 degrees of flexion and his knees at 105 to 120 degrees of extension (Fig. 2). The feet are placed against a vertical Bucky diaphragm and cassette, and the knees and feet are kept separated by a distance of about three inches in both adults and children. The tibial tubercles should be pointing directly anteriorly. For positioning fractious infants, a radiolucent plastic footholder may be used to maintain this three-inch distance between the feet; usually, however, the mother is able to hold the child's feet satisfactorily. The knees

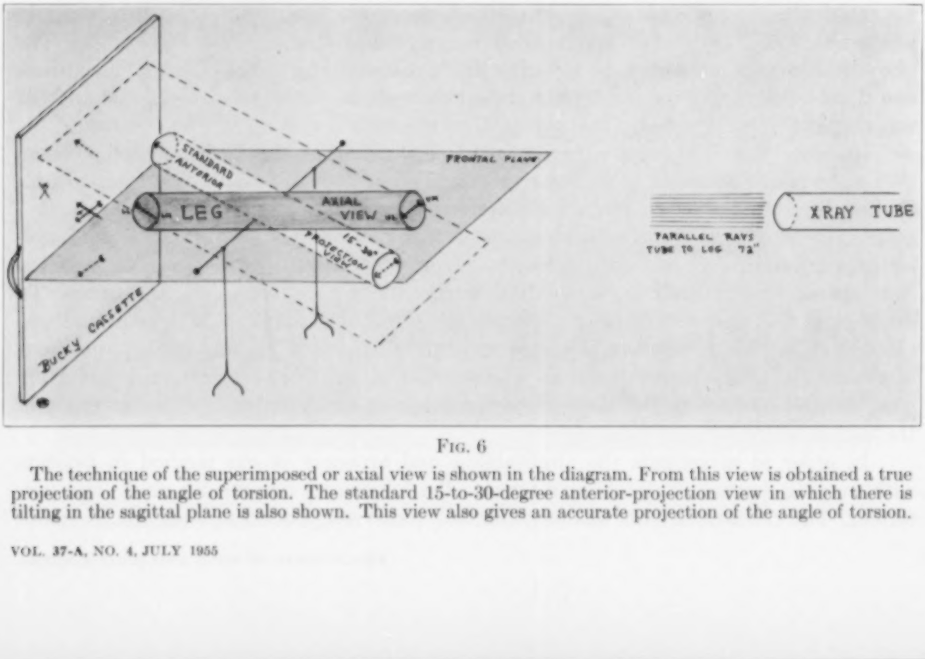
STANDARD ANTERIOR
FRONTAL PLANE
LEG
AXIAL VIEW
15-30° PROJECTION VIEW
BUCKY CASSETTE
PARALLEL RAYS
TUBE TO LEG 72"
XRAY TUBE

Fig. 6

The technique of the superimposed or axial view is shown in the diagram. From this view is obtained a true projection of the angle of torsion. The standard 15-to-30-degree anterior-projection view in which there is tilting in the sagittal plane is also shown. This view also gives an accurate projection of the angle of torsion.

may be held three inches apart by a roll of piano felt kept between the thighs by encircling adhesive strips.

In the sitting position, the patient sits on a stool, adjustable in height, so that the hips are at 90 degrees of flexion and the knees at 105 to 120 degrees of extension. The feet rest on a horizontal Bucky diaphragm and cassette with the knees separated as described.

In both positions, the tube is kept seventy-two inches from the film. This distance is used in order to obtain parallel rays and a minimal distorting effect. The tube is directed perpendicular to the cassette and is aimed at the point mid-way between the centers of the tibiae. The following table should be consulted for details of average roentgenographic technique.

	Kilovolts Peak	Milliampere-Seconds	Distance (*Inches*)	Bucky
Children	60 to 65	50 to 60	72	Yes
Adults	80 to 85	75 to 85	72	Yes

INTERPRETATION OF X-RAY FILMS

Typical roentgenographic appearances obtained by means of this technique in a normal child and in an adult are shown in Figures 3-A and 3-B. The image of the tibiofibular unit varies in length from about three to eight inches, depending upon the size of the subject. The film is studied in order to determine the location of the four points described. A line is drawn joining the two upper points and another line is drawn joining the two lower points; the angle between these two lines is the measure of tibiofibular torsion.

Tibiofibular torsion may be either medial or lateral; this is determined by the direction of the torsion of the distal line (*LL-LM*). When the lines are parallel, there is zero torsion; when the angle made by the two lines points laterally, there is lateral torsion; and when the angle made by the two lines points medially, there is medial torsion. When there is medial torsion, the angle is expressed as minus (−) the number of degrees and when there is lateral torsion, the angle is expressed as plus (+) the number of degrees.

EXPERIMENTAL STUDIES

To determine the accuracy of our method, a series of experiments were performed, in which tibiofibular units, dissected from adult and from stillborn cadavera, were used. The tibiofibular units consisted of the tibia and fibula connected by the interosseous membrane and tibiofibular ligaments. A wire was drilled through the upper two points, and another was drilled through the lower two points, thus graphically establishing the two axes.

Roentgenograms of the specimens were made (1) in the axial or superimposed position, giving the true measure of tibiofibular torsion (Fig. 4) and (2) in various projections, including the standard 15-to-30-degree anterior projection used in our clinical roentgenographic method (Fig. 5). Roentgenograms in many deviations from this standard projection were made in order to determine the distorting effect of any unintentional variation from the standard positioning of the limb during the making of the roentgenogram. To accomplish this, the distal end of the limb was tilted upward 15 to 30 degrees and was tilted to either side 30 degrees. The latter deviations simulated valgus and varus positions of the leg. In addition, combinations of these deviations from the standard projection were used. It was found that these projections do not significantly affect the accuracy of the measurement of tibiofibular torsion.

In order to investigate the applicability and accuracy of our method in patients with varying degrees of tibiofibular torsion, the following experimental study was performed. The tibiofibular unit was osteotomized transversely in its mid-portion. A radiolucent peg was placed in the medullary canal of the tibia, traversing the osteotomy site, so that the tibiofibular torsion could be experimentally produced as desired. In varying degrees of medial and lateral tibiofibular torsion, roentgenograms were made of the specimen in the axial view and in the 15-to-30-degree anterior projection or standard view. The results of this experiment show that in all degrees of medial and lateral torsion tested, the 15-to-30-degree anterior projection does not cause an appreciable error in the measurement of tibiofibular torsion.

It was also found that, if it was assumed that the normal tibiofibular torsion is about +15 degrees of external torsion, the method is applicable over, approximately, a 60-degree range of torsion in either direction.

Our study with the tibiofibular units of infants indicated that tibiofibular torsion could be measured accurately, the same roentgenographic landmarks being used as those in the adult, despite the presence of epiphyses.

The following case history is presented as an illustration of the clinical applicability of this method of measuring tibiofibular torsion.

F. R. (DD 2829), a Puerto Rican boy, two and a half years old, was seen at the Hospital for Joint Diseases, in the Out-Patient Department. The child's feet had turned in since he had begun to walk at the age of one and a half. The impression of several examiners on physical examination, with the patellae and malleoli being used as landmarks, was that the patient had a moderate bilateral medial tibial torsion, with mild metatarsus adductus. The patient was also examined by means of the clinical and roentgenographic

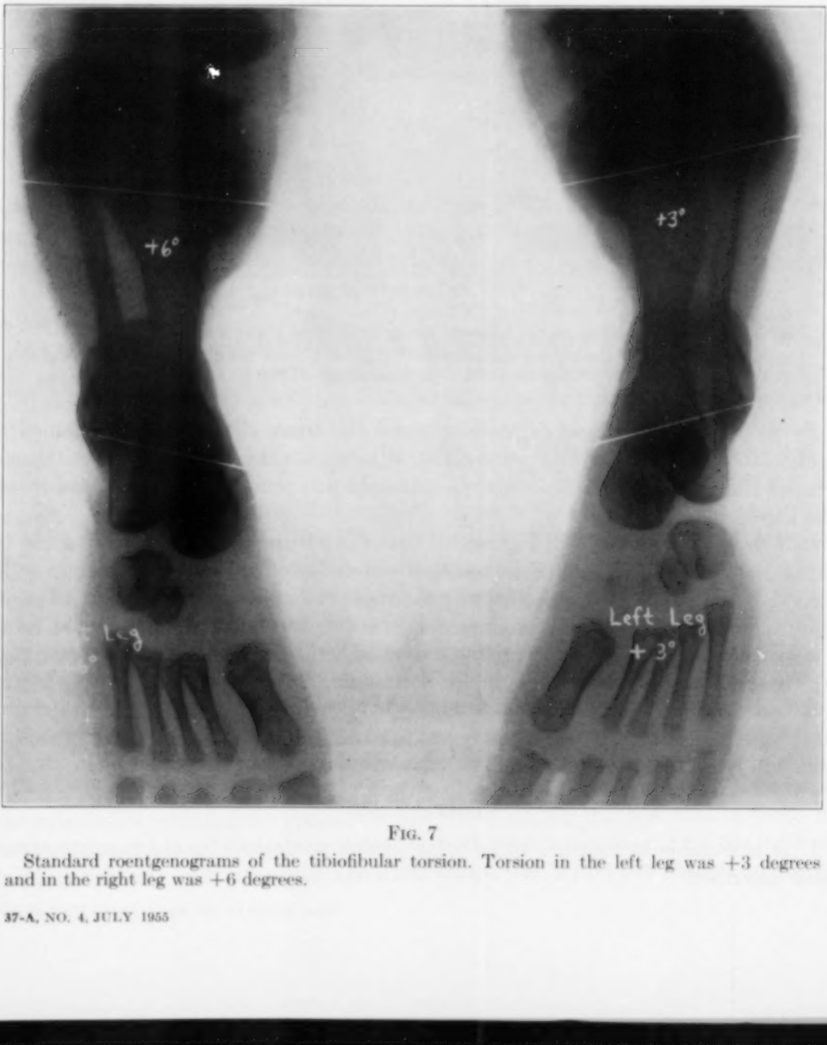

Fig. 7

Standard roentgenograms of the tibiofibular torsion. Torsion in the left leg was +3 degrees and in the right leg was +6 degrees.

technique previously described. Palpation of the four bony landmarks revealed the upper and lower axes to be almost parallel. This was confirmed by measurement of the anterior-projection roentgenogram. The exact figures for the tibiofibular torsion of the two legs, as revealed by this roentgenogram, were +3 degrees on the left, and +6 degrees on the right (Fig. 7). The same roentgenogram revealed minimal metatarsus adductus on the left, none on the right, and no varus deformity of the hind part of the feet, as shown by the normal relationship of the talus to the calcaneus.

Figure 8-A shows the toeing-in deformity with the patient in the sitting position. Figure 8-B shows the correction of this deformity by gentle manual lateral rotation of the left leg on the thigh. It is seen from the change in the position of the malleoli that correction of the deformity occurred proximal to the ankle joint.

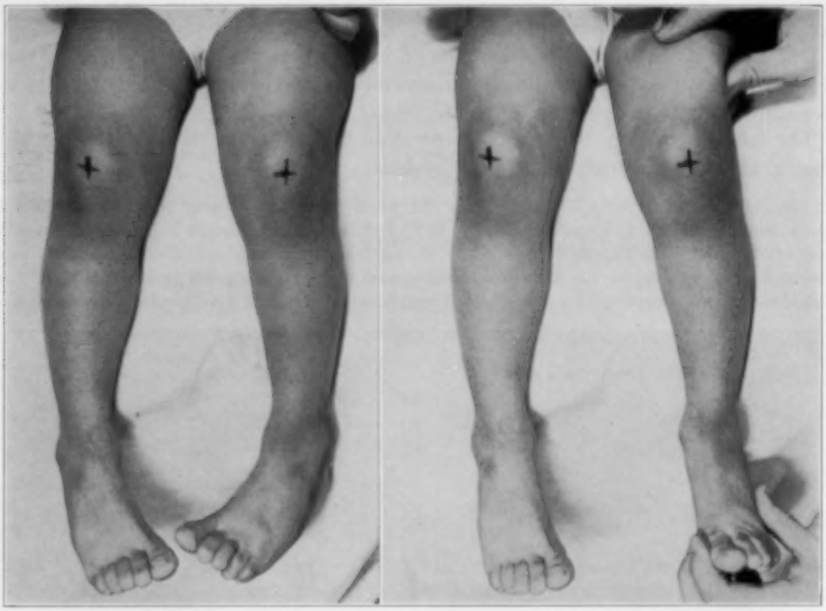

FIG. 8-A FIG. 8-B

Fig. 8-A: Photograph showing the bilateral toeing-in deformity which is worse on the left.

Fig. 8-B: Deformity of the left leg was corrected by gentle passive manual lateral rotation of the leg on the thigh. Note the change in position of the malleoli on the left.

By palpation of the head of the fibula and the point *UM*, it was ascertained that correction took place at the knee joint rather than within the leg itself. It was, therefore, concluded that the toeing-in deformity in this child was primarily due to medial rotation at the knee joint.

It is to be further noted in Figure 8-B that the position of the patella had not been changed despite the correction of the toeing-in deformity of the left leg. Thus it is demonstrated that the patella has no constant relationship to the tibiofibular unit and cannot, therefore, be accurately used as a landmark in the measurement of tibiofibular torsion.

A large number of similar cases of pigeon-toe have been studied but are not reported here. The results of our roentgenographic technique in these cases indicate a surprising lack of true tibiofibular torsion. In most cases, as in the one presented here, the deformity is due to medial rotation of the entire leg at the knee. In our experience, such cases have responded favorably to lateral rotation treatment in a Denis Browne splint.

CONCLUSIONS

1. It is possible to measure tibiofibular torsion accurately by the roentgenographic method described.

2. The method is applicable to torsion ranging from −45 degrees of medial torsion to +75 degrees of lateral torsion.
3. The method is applicable to both adults and children.

NOTE: The authors wish to thank Dr. Maurice M. Pomeranz, Director of Radiology at the Hospital for Joint Diseases, for his assistance and for providing the facilities for this work, and Dr. Emanuel B. Kaplan, Attending Orthopaedic Surgeon at the Hospital for Joint Diseases, for his helpful suggestions.

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LOCAL INFILTRATION ANAESTHESIA FOR KNEE-JOINT SURGERY

BY LIEUTENANT COLONEL ROBERT W. AUGUSTINE, CAPTAIN WM. R. MACAUSLAND, JR., AND FIRST LIEUTENANT WILLARD F. GREENWALD,

Medical Corps, United States Air Force

From the 3810th United States Air Force Hospital, Maxwell Air Force Base, Alabama

Local infiltration anaesthesia for knee-joint surgery is effective, uncomplicated, easily accomplished, and well accepted by the patient. This opinion is based upon 125 consecutive major orthopaedic operations upon the knee joint which have been done in the past two years at our Hospital. In these two years, all knee-joint surgery has been done under local infiltration anaesthesia, and all of the operations were completed without other forms of anaesthesia. Our procedure, which is but an adaptation of older techniques[1, 3, 5, 6], is herein reported because of advantages over other methods of which some surgeons may not be aware.

Our technique is essentially to flood the soft tissues with a dilute solution of an anaesthetic agent. This allows immediate progress of surgery and ensures a dry field and an anaesthesia of two to four hours' duration. The injection technique is easily mastered and can be performed quickly. A small skin wheal is raised by the use of a 26-gauge needle. Then with a 22-gauge three-inch needle, the subcutaneous tissues are distended for several inches beyond the proposed incision on each side. The skin lymphatics along the line of the proposed incision are next distended with the anaesthetic agent, and then the skin and subcutaneous tissues are incised down to the fascia. A waiting period before making the incision is unnecessary, as anaesthesia of the skin occurs immediately. Before the fascia is incised, it should be infiltrated carefully, because manipulation of ligamentous tissue may cause great pain. The wound may be extended in any direction during the operation simply by further infiltration, and, with practice, structures at some distance may be completely anaesthetized before dissection is begun.

This method yields immediate and absolute anaesthesia. The patient may feel bone vibration due to proprioceptive innervation, and occasionally may feel pressure in distant tissues during retraction, but this does not cause discomfort. There is mild distress during the infiltration, due to distention of the tissues. Muscle spasm has not been noted in over 1,500 consecutive orthopaedic operations completed during the past two to three years under local anaesthesia. Normal tissues are anaesthetized more readily by the infiltration technique than scarred or otherwise abnormal tissue. The structures about a joint are in-

TABLE I

RELATIVE SENSITIVITY OF TISSUE *

Tissue	Degree of Sensitivity
Cortical bone	Insensitive
Fat	
Muscle **	
Cancellous bone	Mildly sensitive
Tendons	
Vessels	Quite sensitive
Nerves	
Fascia	
Skin	

* Based on seventy-five tests made on twenty members of the orthopaedic surgical and nursing staffs. Cortical bone was found to be insensitive to all stimuli employed, including drilling, except heat; bone is, however, sensitive in areas in which the penetrating Sharpey's fibers are present. The bones tested included the pelvis, femur, tibia, and some of the bones of the foot.

** Sensitive to anoxia.

filtrated more readily than those elsewhere, because of the relatively small volume of the overlying tissues. Small areas are more easily anaesthetized than large ones; fracture areas of large bones are the most difficult. However, almost any procedure upon somatic tissues can be accomplished readily under local infiltration anaesthesia. Inflammation and hyperaemia make this method less effective but do not prohibit its use. All surgery performed in the presence of infection has been done under local anaesthesia, and no untoward effects have been noted.

Other measures of importance in this form of anaesthesia include preoperative nutrition, sedation, and psychological preparation. We insist that the patient about to undergo elective surgery have breakfast before operation, and we encourage him to take coffee and fluids by mouth during the surgery. This plan was adopted because so many patients complained of hunger during the procedure. Vomiting in the operating room has not occurred. It seems possible that a full stomach may supply serum amino acids and glucose that are of value during operation. Patients rarely miss a meal postoperatively and appear to be normal in every respect. The most impressive features of this anaesthesia, however, have been the lack of bleeding and the postoperative well-being of the patient.

All sedation is given intravenously in the operating room, small doses of selected drugs

TABLE II

MAJOR KNEE OPERATIONS PERFORMED UNDER LOCAL INFILTRATION ANAESTHESIA
(125 Operations)

Surgical Procedure	No. of Cases
Arthrotomy for torn meniscus * or osteochondritis dissecans	92
Removal of tumors or biopsy specimens, or synovectomy	9
Tendon transplantations about knee and repair of ligamentous defects	14
Excisions of cysts of the popliteal space	4
Repair of patellar fracture	4
Fracture of tibia or femur, or both, close to the knee joint	2
Total	125

* The average time needed for a meniscectomy, including anaesthesia time and skin closure, was slightly less than one hour.

being used. The patient may need sedation at two times during the procedure,—first, before operation to allay apprehension, and, second, toward the end of a long or complicated procedure, when the patient becomes uncomfortable because of being in one position so long. Narcosis from sedative drugs should be avoided, since this fosters anoxia and postoperative somnolence, eliminating some of the advantages gained by the use of local infiltration anaesthesia. Preoperative medication in therapeutic dosage has not been shown to favorably affect the minimum toxic dose of modern anaesthetic agents. The impressions to the contrary given in the literature[7] are not supported by revealing experimental work. Cerebral stimulation as evidenced by tic, fasciculations, and convulsions, occurring in the course of the use of a local anaesthetic agent, may be interpreted as release phenomena due to depression of controlling centers. Such signs indicate a basic brain-stem depression which is the over-all effect of a toxic dose of a local anaesthetic agent. In this series of cases, depression of the central nervous system was not evident in a single patient. These complications are best avoided by the operator through an exact knowledge of the toxic limit of his drug and through conducting his anaesthesia accordingly. Symptoms due to allergy or sensitivity to the local anaesthetic agent have not been observed in over 1,500 recent cases in which this anaesthesia was used.

Preoperative drugs seem to influence the mental state of the patient and little else. Euphoria or an unconcerned relaxed state of mind is the objective of preoperative medication. A drink of whiskey, a combination of demerol and scopolamine intravenously in appropriate doses, or occasionally pentobarbital given orally are usually adequate for this purpose.

The psychological management of the patient under local anaesthesia requires no more than a display of confidence by all concerned and verbal diversion by the nurse at the head of the table. The anaesthetic is not discussed with the patient and few inquire concerning it. The nurse at the head of the table is the ward nurse whose only duty during the surgery is to observe the patient. She should receive specific training for her duties. Conversation among the staff need not be restricted, as experience has shown that it does not concern the patient. The ability of the surgeon to anaesthetize the operative field and to be aware of the extent of anaesthesia is the most important factor in the management of the patient.

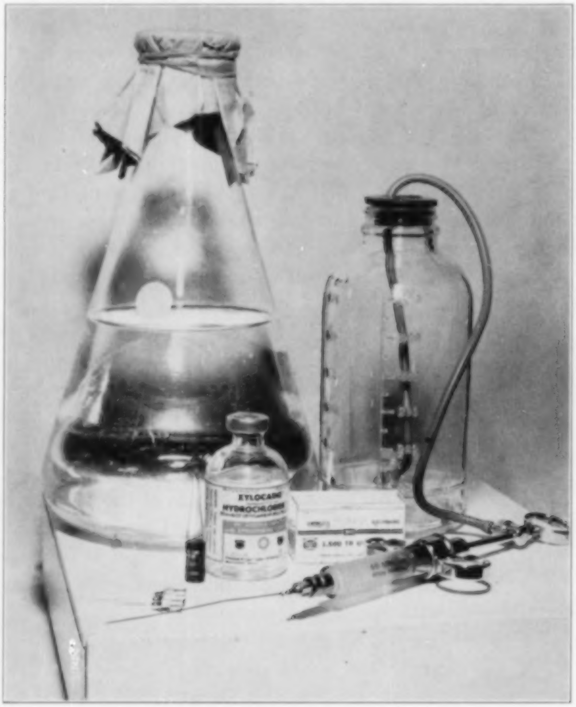

FIG. 1

Equipment and drugs useful in local infiltration anaesthesia.

The solution we use is composed of xylocaine 0.166 per cent. (one-sixth of one per cent.), adrenalin 1:1,200,000, and hyaluronidase in a concentration of two and one-half turbidity-reducing units per cubic centimeter of solution (Fig. 1). This solution is made up by placing a fifty-cubic-centimeter vial of 2 per cent. xylocaine with adrenalin 1:100,000 in a 600-cubic-centimeter bottle, of the type used for blood transfusions, and adding saline to the 600-cubic-centimeter mark and 1,500 turbidity-reducing units of hyaluronidase. A mechanical syringe connected by rubber tubing to the outlet of the bottle stopper facilitates the injection of the solution. For a single total meniscectomy, about 400 cubic centimeters of this solution is used. This volume may be greater than that customarily used by others, but this amount is an essential part of the technique. The xylocaine in a concentration of 0.166 per cent (one-sixth of one per cent.) of drug is optimum,—in fact, one-eighth of one per cent. (0.125 per cent.) is adequate. More than one-sixth of one per cent. adds drug to the body unnecessarily. This is the concentration of drug recommended; its effectiveness has been borne out in practice. The adrenalin in a concentration of 1:1,200,000 has proved to be ideal. Experiments on patients based on the use of greater concentrations have shown no advantage. This low concentration lessens the possibility of an adrenalin reaction or of delayed bleeding. The chief value of adrenalin, in our opinion, is that it fixes the anaesthetic agent in the tissues. If the xylocaine is used with hyaluronidase without adrenalin, the anaesthesia is of less duration. Capillary bleeding is lessened by the hydrostatic pressure of the injected solution; this does not lead to delayed bleeding. The enzyme, hyaluronidase, increases the permeation of the anaesthetic solution through the areolar tissue and is in no way harmful. This is a valuable effect and should not be neglected.

The effect of introducing such an amount of fluid about a knee joint is apparently innocuous. We have observed no deleterious effects. The tissue changes from local infiltration are, in brief, distention, slight fragmentation of muscle cells, occasional minute hemorrhages, and within a few hours perivascular white-cell infiltration. All of these changes resolve in about three days and are fairly insignificant[4].

We have had no complications following surgery on the knee which were related to the anaesthesia, and few of any nature.

Knee surgery is often done under tourniquet and general anaesthesia, and this procedure is advised in some standard texts[2]. A tourniquet, however, introduces complications of its own and is unnecessary in the described procedure.

Advantages of the procedure described here are as follows:

1. Airway control is retained by the patient.
2. Capillary bleeding of the wound is lessened.
3. Postoperative physiological state of the patient is normal.
4. Adequate nutrition is maintained during surgery.
5. There is no need for a recovery period as from general anaesthesia.
6. There are none of the complications, such as transverse myelitis, which are occasionally seen with spinal anaesthesia.
7. There are no tourniquet complications.
8. An anaesthetist is not required.

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THE TIBIALIS POSTERIOR TENDON AS AN OBSTACLE TO REDUCTION OF A LATERAL ANTERIOR SUBTALAR DISLOCATION

BY CAPTAIN RICHARD D. MULROY, *Medical Corps, Army of the United States*

From the Orthopaedic Service, Tokyo Army Hospital

A subtalar dislocation is actually a dislocation of the talocalcaneal and talonavicular joints. The talus remains in its normal position between the malleoli, while the talonavicular and the anterior, middle, and posterior talocalcaneal joints are dislocated. The calcaneocuboid and all other tarsal joints remain intact.

This dislocation has been classified into medial, lateral, anterior, and posterior types. Speed states that the medial dislocation is the most common, and most authors describe the medial posterior dislocation as a medial dislocation for brevity. Bonnin refers to Malgaigne's two varieties of lateral subtalar dislocation. In the first type, "The posterior subtaloid joint is intact and the rest of the tarsus swings laterally around this, thus externally rotating the foot". In the second type, "The whole tarsus is shifted directly laterally under the talus". Bonnin felt that all anterior dislocations were doubtful because they were all reported in the "pre-radiological era". He also doubted the existence of posterior dislocations, but Leitner reported one case in 1950.

Leitner found forty-two recent cases of subtalar dislocation in 4,125 cases of traumatic dislocation; five of these were lateral. In a review of the literature he found 162 cases of medial dislocation and fifty-nine cases of lateral dislocation. Of these cases of lateral dislocation, nine showed obstruction.

Leitner's five cases of lateral dislocation were all reduced by closed methods. Only one showed an obstacle to reduction. This was reduced after several manipulations by Böhler's manoeuvre. Leitner considered that the tibialis posterior tendon had been dislocated forward from its groove and was wrapped around the lateral aspect of the talus. Roentgenograms revealed a lateral inferior and posterior dislocation. By dorsiflexion of the foot he felt that he had removed the obstructing tibialis posterior tendon. Smith performed an open reduction on his only recent case of lateral dislocation because of unsuccessful attempts at reduction by manipulation. The roentgenograms revealed a lateral dislocation with anterior displacement of the foot, the calcaneus pointing superiorly and the talus inferiorly. At operation, the head of the talus was found to be displaced across the tibionavicular and calcaneonavicular ligaments. Roentgenograms of Plewes and McKelvey's Case 1 showed a lateral anterior dislocation of the talus. After manipulation had failed, strong skeletal traction through the calcaneus was maintained for one hour, and then, with traction still being maintained, a Thomas wrench was used to gently force the talus into position.

W. P. R., a twenty-year-old soldier, was walking across an overpass, approximately fifteen feet above a small roadway, at 10:30 P.M. on July 24, 1954. The patient was intoxicated at the time, and his memory was not too clear as to the details, but instead of walking straight across the overpass, he stepped off the side and fell feet first, landing on his right foot. He sustained an incapacitating injury to his right foot, was unable to walk, and lay in the roadway until he was picked up and carried to the Tokyo Army Hospital.

Clinical findings on admission: The right foot was markedly swollen and ecchymotic with obvious lateral dislocation of the foot. The head of the talus was protruding medially and inferiorly with the skin tense and ecchymotic over the protruding head of the bone. There was hypo-aesthesia of the plantar aspect of the foot, but the sensation over the dorsum of the foot was intact. The pulse in the dorsalis pedis was good. Roentgenograms revealed a complete lateral dislocation of the foot. The talus was still resting in the ankle mortise between the malleoli, but there was lateral, anterior, and superior displacement of the other tarsal bones. The superior surface of the calcaneus was lying at the level of the ankle joint and was displaced forward about a third of its length. The fibula and the ankle mortise were intact. There were small chip fractures of the calcaneus and the talus (Figs. 1-A and 1-B).

Treatment and progress: The patient was given pentothal and nitrous-oxide anaesthesia. With the application of strong traction and countertraction in the axis of the leg, the foot was forcibly plantarflexed and pushed medially, without success. Then Böhler's manipulation was attempted; strong traction and countertraction were applied and the foot was dorsiflexed and pushed medially. However, after many at-

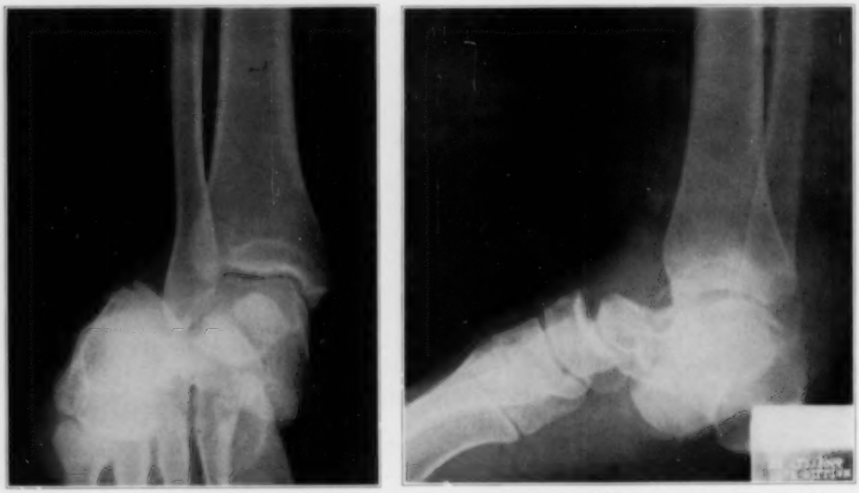

Fig. 1-A

Fig. 1-B

Roentgenograms made immediately after injury.

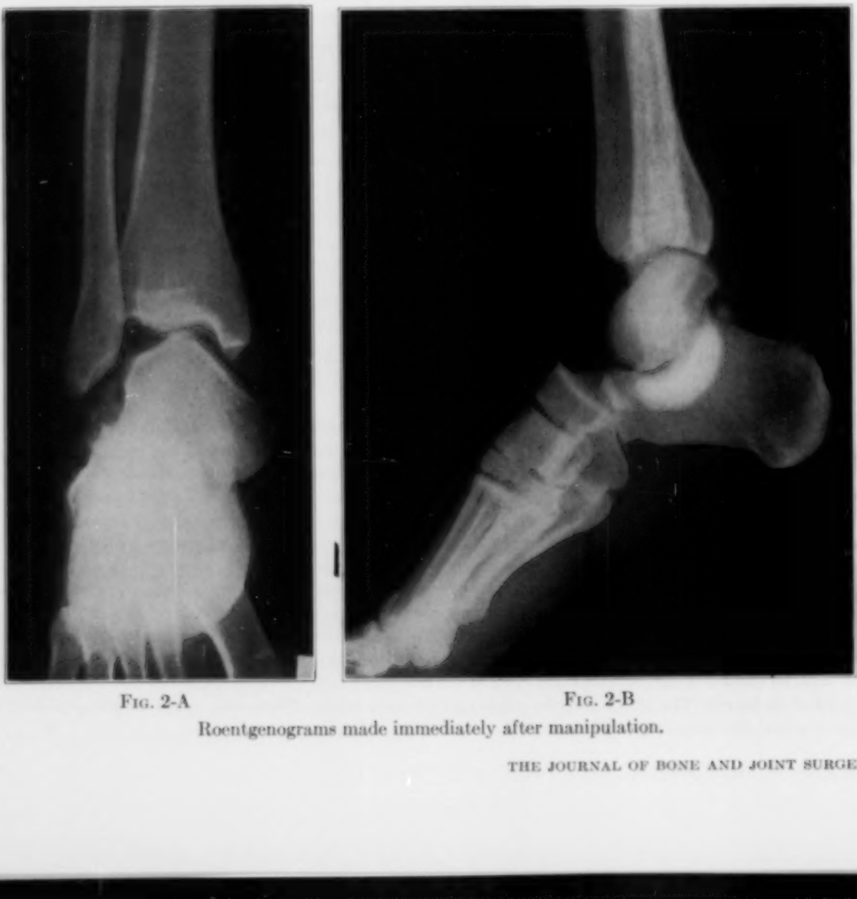

Fig. 2-A

Fig. 2-B

Roentgenograms made immediately after manipulation.

tempts, it appeared that reduction could not be accomplished. Check roentgenograms were made. The superior and anterior dislocation of the foot had been corrected; however, the talus was now tilted 45 degrees in the ankle mortise and pointing 45 degrees medially and inferiorly because of the medial thrust of the other tarsal bones (Figs. 2-A and 2-B). The calcaneus lay in almost its normal position inferior to the malleoli. There was obviously an obstacle to reduction, and the tibialis posterior tendon was considered the most probable cause.

There was so much swelling about the foot and ankle that the tibialis posterior tendon could not be palpated. Therefore, the patient was immediately prepared for operation. A slightly curved incision, 6.25 centimeters long, was made anterior to and below the medial malleolus. The head and neck of the talus were exposed. The tibialis posterior tendon was found to have become displaced over the head of the talus and was tightly stretched about the neck of this bone, thus holding the dislocated tarsal bones lateral to the talus and preventing reduction (Fig. 3). The plantar insertion of the tibialis posterior tendon was intact and the tendon had remained in its groove behind the medial malleolus. The tendon was levered back over the head of the bone and reduction was easily accomplished by manipulation (Figs. 4-A and 4-B). The incision was closed, a sterile compression dressing was applied, and the extremity was immobilized by means of a posterior plaster splint.

The postoperative course was uneventful except for delayed healing of the incision.

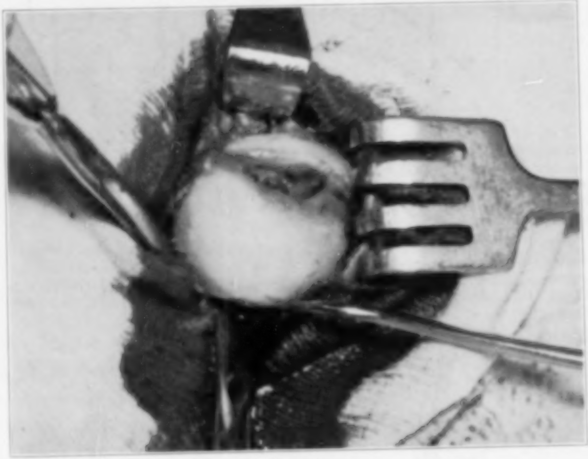

FIG. 3

Conditions found at operation.

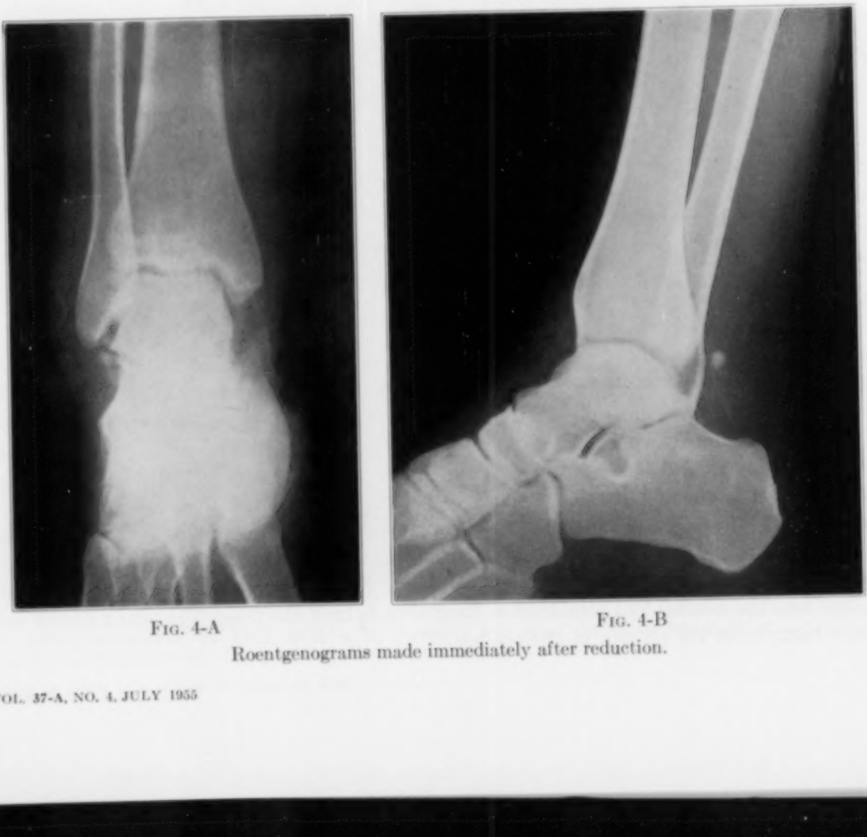

FIG. 4-A

FIG. 4-B

Roentgenograms made immediately after reduction.

The circulation was excellent and all swelling subsided. The extremity was immobilized for six weeks. At the end of this time the incision was healed and the patient began weight-bearing. The tibialis posterior tendon could be palpated in its normal position; it could not be moved in its groove and was functioning strongly. Four months after operation, the range of motion in both the ankle and the subtalar joints was complete. The patient had no complaints.

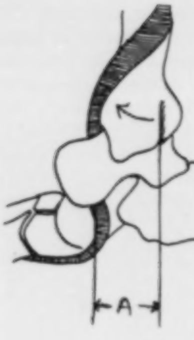

FIG. 5

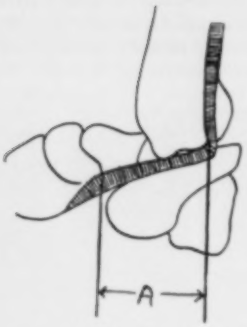

FIG. 6

Fig. 5: Leitner's conception of the new course of the tibialis posterior tendon in lateral posterior and inferior subtalar dislocation; the tendon has slipped laterally and forward and has come to lie in front of the medial malleolus, hooked around the neck of the talus. The foot is dislocated posteriorly and inferiorly; thus distance *A* is decreased.

Fig. 6: The drawing indicates the probable course of the tibialis posterior tendon before manipulation in the author's case. The distance *A* is increased because of the forward dislocation of the foot. Thus, the course of the tendon is increased more than if the foot were dislocated posteriorly.

COMMENT

In this case, the foot was dislocated anteriorly and superiorly, as well as laterally. Leitner's case was dislocated laterally, posteriorly and inferiorly. On examination of the roentgenograms presented in Plewes and McKelvey's Case 1 and Smith's Case 2, it is seen that these patients had lateral, anterior, and superior dislocations, although the authors describe them only as lateral. It would appear that in most cases there are anterior or posterior, and inferior or superior components.

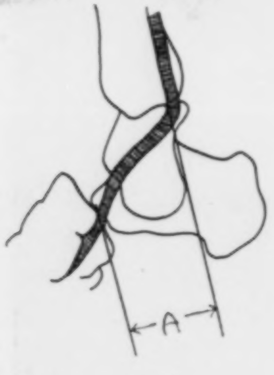

FIG. 7

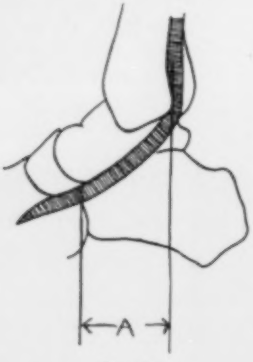

FIG. 8

Fig. 7: After correction of the anterior and superior dislocation as seen at operation, the distance *A* is equal to that of the normal foot.

Fig. 8: Normal relationships of tarsal bones and the tibialis posterior tendon.

In the author's case, the exact position of the tibialis posterior tendon was seen. The plantar insertion was intact and the tendon had remained in its groove as it curved laterally and superiorly over the neck of the talus. Since Leitner performed a closed reduction, he could not see the tibialis posterior tendon at operation. However, he assumed that the plantar insertion was intact. He felt that only through anterior displacement of the tendon from its tibial groove could increased tendon length be obtained for the increase in the course of the tendon. This he illustrated with drawings in which the tendon is displaced anteriorly and passes laterally about the neck of the talus. In his case, the foot was displaced posteriorly, thus shortening the actual distance between the groove in the tibia and the navicular (Fig. 5). However, in the author's case, the foot was dislocated anteriorly, thus increasing the distance between the navicular and the tibial groove (Fig. 6). Yet on direct examination at operation, the plantar insertion of the tendon was intact and the tendon had remained in its groove behind the tibia. The extra length must have come from the stretch of the tendon.

NOTE: At the time this patient was under treatment at the Tokyo Army Hospital, Col. Vinnie H. Jeffress was Chief of the Orthopaedic Service and Capt. Daniel E. Curtin was the Ward Orthopaedic Surgeon. The author would like to express his appreciation to them.

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HORSESHOE-SHAPED BAKER'S CYST OF THE KNEE

REPORT OF A CASE

BY BRUCE M. CAMERON, M.D., AND FRANK O. McGEHEE, M.D., HOUSTON, TEXAS

This case of a Baker's cyst of the knee joint with two pedicles is reported because no similar case was noted in a review of the literature.

Since 1840, when Adams reported an enlargement under the medial head of the gastrocnemius muscle which he thought was due to arthritis, relatively few articles have been written on this subject. There have been several schools of thought regarding etiology: Adams and Haggart thought that these cysts were herniae through the posterior capsule

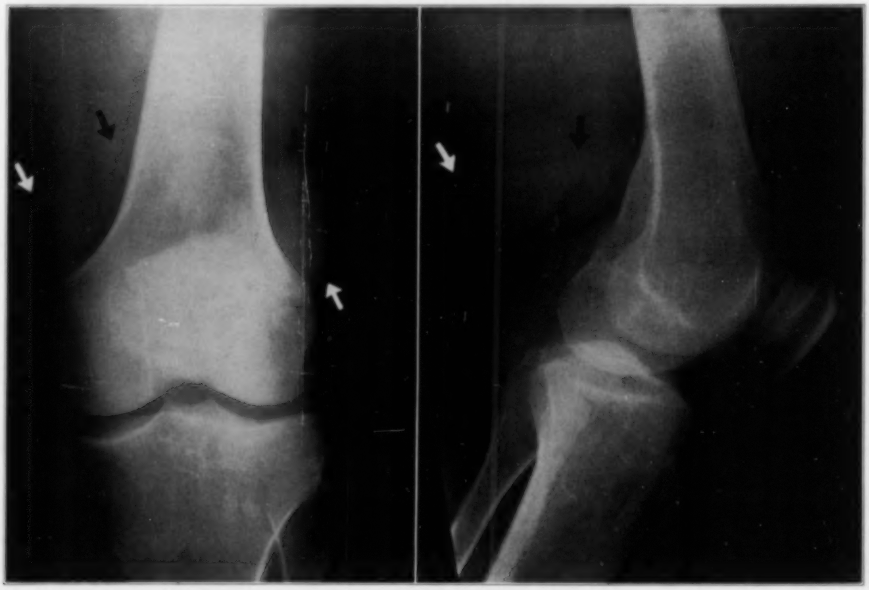

FIG. 1

Roentgenograms of the knee, showing an abnormal soft-tissue outline in the popliteal fossa but no intra-articular or bony changes.

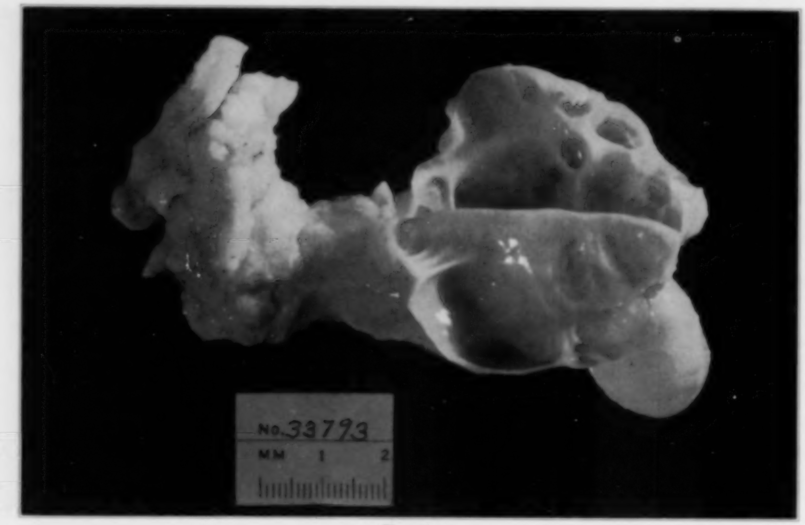

Fig. 2
Photograph demonstrating the size of the gross specimen.

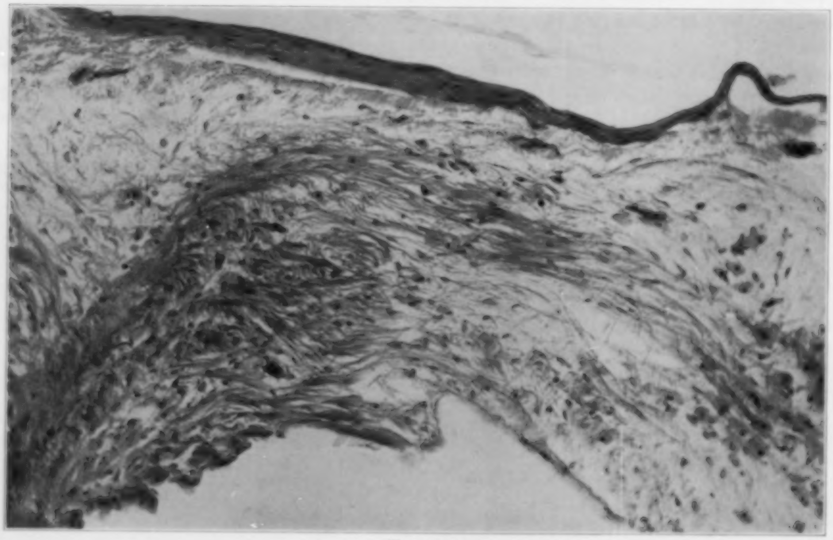

Fig. 3
Photomicrograph (× 110) showing the lining of the cyst.

of the knee. Wilson, Eyre-Brook, and Francis thought they represented enlargements of the normal gastrocnemio-semimembranosus bursa, whereas Meyerding and VanDemark and Baker[2,3] thought that they were due to either herniae or enlargement of bursae. All agreed that the symptoms were usually insidious in onset, involving males in the ratio of two to one, and that the signs were those of tumefaction and internal derangement of the knee. All agreed that the treatment of choice was surgical excision with ligation of the pedicle if one existed.

Case No. 11027. When this white male, thirty-eight years old, was first seen on July 18, 1954, he stated that in October 1951 a heavy piece of iron had struck the back of his knee, causing him minor pain and disability. Shortly thereafter, his job required an increased amount of walking, and, as a result, a shot-sized tumor had developed on the posterolateral side of the knee. There had also been intermittent generalized swelling, and each time that this swelling receded the patient thought that the lateral tumor had grown larger. About a year after the initial trauma, the tumor had gradually enlarged, extending into the popliteal fossa where it had rapidly expanded to its final size and remained constant for one year. A week prior to admission, he stepped out of an automobile and twisted his knee. There was a loud snap followed by pain in the medial portion of the joint but no swelling. Three days later, with continued weight-bearing, the knee had swelled and had become unstable and painful.

His history showed that the patient had had typhoid (1927), typhus (1943), and a herniorrhaphy (1951).

General physical examination was normal, but examination of the left knee revealed a large, fluctuant, fixed, moderately tender mass in the popliteal fossa, the main portion of the tumor being below the joint crease. Flexion and extension were limited 10 degrees, with pain being noted posteriorly on forcing these motions. No synovial thickening or swelling was noted anteriorly and all of the ligaments were normal. The neurovascular status of the leg was normal.

Roentgenograms of the knee showed that the bones and joints, *per se*, were normal but that there was an abnormal soft-tissue outline in the popliteal fossa (Fig. 1). The rest of the laboratory tests, including complete blood count, urinalysis, sedimentation rate, and chest plate were normal.

The patient was admitted to Methodist Hospital (Case No. 46,213) and was operated upon June 22, 1954, under a general anaesthetic. The left knee was prepared and draped in the routine manner. Through a posterior bayonet incision, a large cyst was exposed in the popliteal fossa. It was horseshoe in shape and was found to be attached to the knee-joint cavity by two distinct pedicles. The first pedicle was attached laterally under the tendon of the biceps femoris muscle, and the second was attached under the medial head of the gastrocnemius muscle. The pedicles were ligated, inverted; the knee incision was closed in layers in the routine manner; and a long cylinder cast was applied.

Grossly (Fig. 2), the cyst was large (12 by 5 by 3.5 centimeters), tense, and multilocular, and had two pedicles. It was smooth, thin-walled, and contained a viscid, yellow fluid. Microscopically (Fig. 3), the wall was compressed, fibrotic, and hyalinized and showed a scattered inflammatory response.

The patient's postoperative course was uneventful, and he was able to return to work July 7, 1954, two and one-half weeks after operation. He was examined six months after operation and found to have no positive signs or symptoms referable to the knee joint.

DISCUSSION

After excision of the cyst, there were no signs of any other pathological condition of the knee joint which would have caused increased intra-articular pressure. It was unlikely, therefore, that the etiology was of a mechanical nature nor did the cyst seem to be a herniation; it would seem more reasonable to assume that the cyst was extra-articular, probably an enlargement and fusion of two of the bursae of the knee.

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MULTIPLE-PURPOSE TONGS *

BY WALKER REYNOLDS, JR., M.D., ANNISTON, ALABAMA

It is the purpose of this paper to describe a pair of tongs which may be used for corrective traction in several different types of fractures.

DESCRIPTION OF TONGS

The tongs were developed chiefly for use in sternal traction and for fixation of sternal fractures with coexisting anterior paradoxical respiration (Fig. 1). In addition, they have been found useful for rib traction in lateral paradoxical respiration (Fig. 3), for skull traction in cases of fractures of the cervical vertebrae (Fig. 5), and for Steinmann-pin or Kirschner-wire traction in fractures of long bones (Fig. 7).

The tongs are made of stainless steel and have the following features:

1. There is a metal loop at the top of the tongs which has a hole in its apex for a rope. The rope is pulled through the hole and secured to the instrument by a knot at the end which remains inside the loop. This arrangement makes possible traction with a central pull.

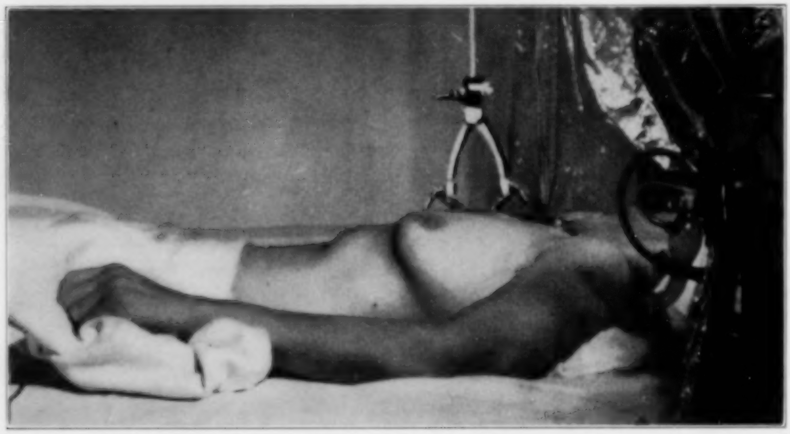

FIG. 1

Sternal traction in a patient with marked anterior paradoxical respiration. The patient had had a tracheotomy, but it failed to control the paradoxical respiration.

2. The tongs may be locked in the desired spread position by a bolt with a nut on each side of the arm of the tongs; the locking device is tightened as desired after the tongs have been anchored.

3. At the end of each arm of the tongs, there is a smaller adjustable arm which may be set and locked at the desired angle by tightening the nuts on the bolt. This angle may be varied from an acute to an obtuse angle, as the arm moves through an arc of approximately 60 degrees.

4. The small adjustable arms have removable points, which are secured in place by Allen screws. There are several types of points available, and additional points may be made easily. One type is for sternal traction, one for rib traction, and the others are for skull traction. When the points are removed, the arms will accommodate Kirschner wires

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* The description of this instrument is taken in part from a thesis submitted to the Faculty of the Graduate School of Medicine of the University of Pennsylvania toward the requirements for the degree of Master of Medical Science for graduate work in surgery.

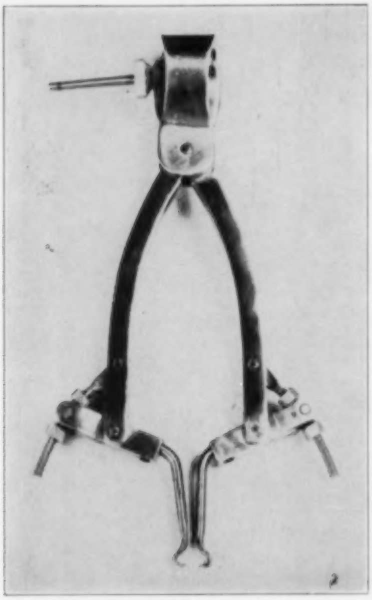

FIG. 2

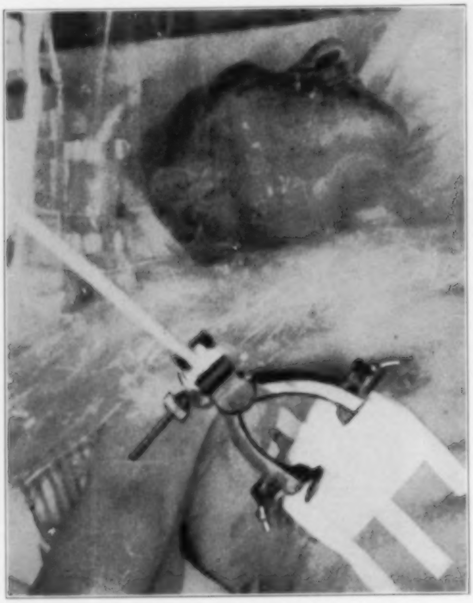

FIG. 3

Fig. 2: Tongs with points set for rib traction.

Fig. 3: Rib traction in a patient with marked lateral paradoxical respiration. The patient had also had a tracheotomy which was not sufficient to control the paradoxical respiration.

or Steinmann pins, which may also be locked in position by tightening the Allen screws. When the tongs are spread to their widest position and curved points are used, the tongs will accommodate the largest skulls.

METHODS OF USE

Sternal Traction

The tongs were devised chiefly for sternal traction and have been used for this purpose by the author in several cases of paradoxical respiration which was uncontrollable by tracheotomy alone (Fig. 1). Under local anaesthesia, a vertical incision approximately two centimeters in length is made in the mid-line over the upper third of the body of the sternum. A second incision is made in the mid-line over the lower third of the body of the sternum. Holes are then made in the outer plate of the upper and lower thirds of the body of the sternum by means of a Crutchfield drill with guarded drill points. The adjustable side arms of the tongs are then set at the maximum obtuse angle. The special, curved, guarded points are placed into the drill holes, and the tong arms are tightened until the tongs are fixed securely in the body of the sternum. The rope is then run through an overhead pulley and five to ten pounds of weight is added. Sterile dressings are applied about each point of the tongs where it enters the skin. The tongs should be tightened every two to three days to prevent slipping.

The advantages of this type of sternal traction are these:

1. There is a more even distribution of traction and a greater part of the body of the sternum is included in the pull of the tongs than with, for example, the towel-clamp method. This means a better stabilization of paradoxical respiration in patients in whom the sternum and anterior chest wall are mobile and oscillating.

2. There is less possibility of the tongs slipping, as the tong points are curved and go through the outer plate of the sternum. The tongs may be tightened easily, in order to

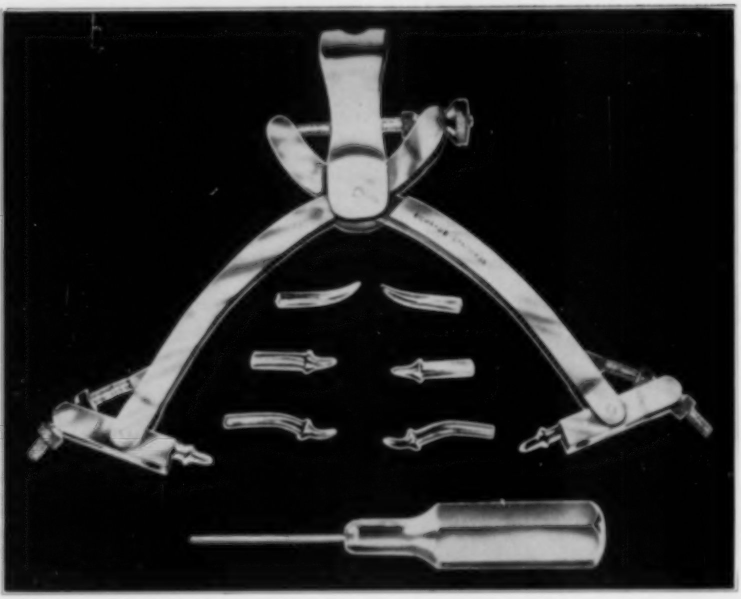

FIG. 4

Tongs with points set for skull traction. An Allen screwdriver and miscellaneous points are also shown.

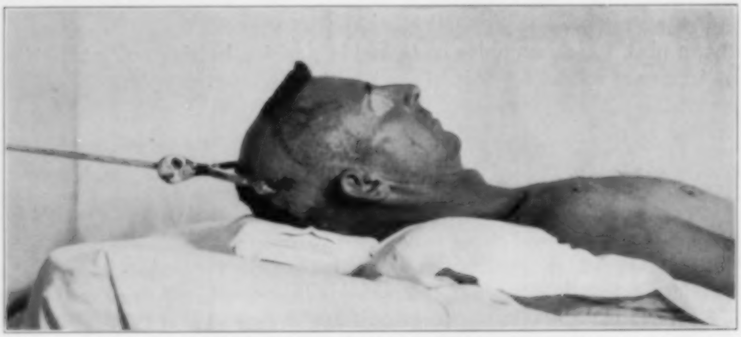

FIG. 5

Tongs applied to the skull for cervical traction.

keep the points secure in the drill holes. If they should slip, the skin traction will hold the points without too much discomfort until they can be replaced in the sternum.

The tongs are also quite useful when there is an associated sternal fracture. They not only serve for sternal traction but also, by virtue of their viselike action, they clamp the two fragments of the sternum together until the fracture has healed.

These tongs fulfill the requirements for ideal traction in paradoxical respiration as advocated by Heroy and Eggleston, who state that they must: (1) control the paradoxical motion of the chest wall adequately, (2) be simple and easy to apply, (3) be capable of withstanding ten pounds of pull for a period of two to three weeks, if traction is employed, and (4) be applied at a distance from the costal cartilages to prevent chondritis.

Rib Traction

The tongs may be used for rib traction (Fig. 2) in cases in which there is a lateral oscillating plaque of double fractured ribs moving paradoxically with respiration. The tongs were used on such a patient (Fig. 3) in whom a tracheotomy had first been done with only limited success. The patient showed a further reduction in the paradoxical movement when rib traction was applied. The points for rib traction were made from Babcock forceps which fit the curve of the rib satisfactorily with minimal danger of perforation of the pleura.

The technique for application of the tongs consists in making a small incision under local anaesthesia over the central rib lying in the oscillating plaque. Then the rib is freed

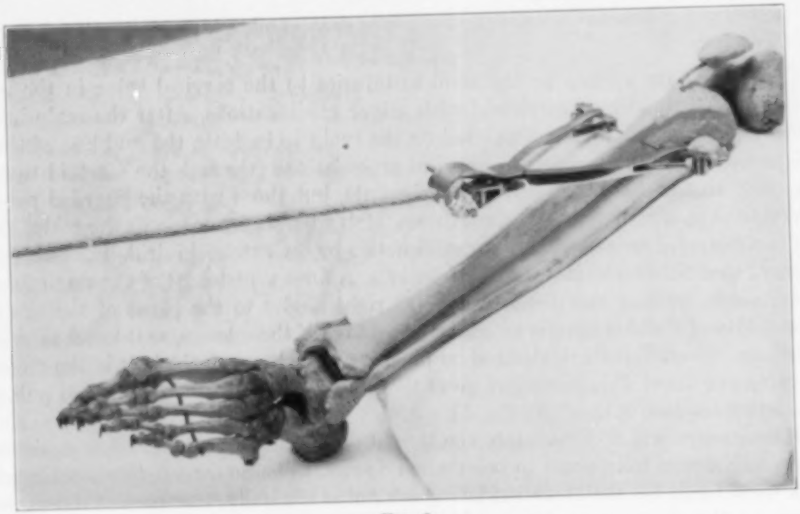

FIG. 6
Tongs applied to a Steinmann pin through a tibia

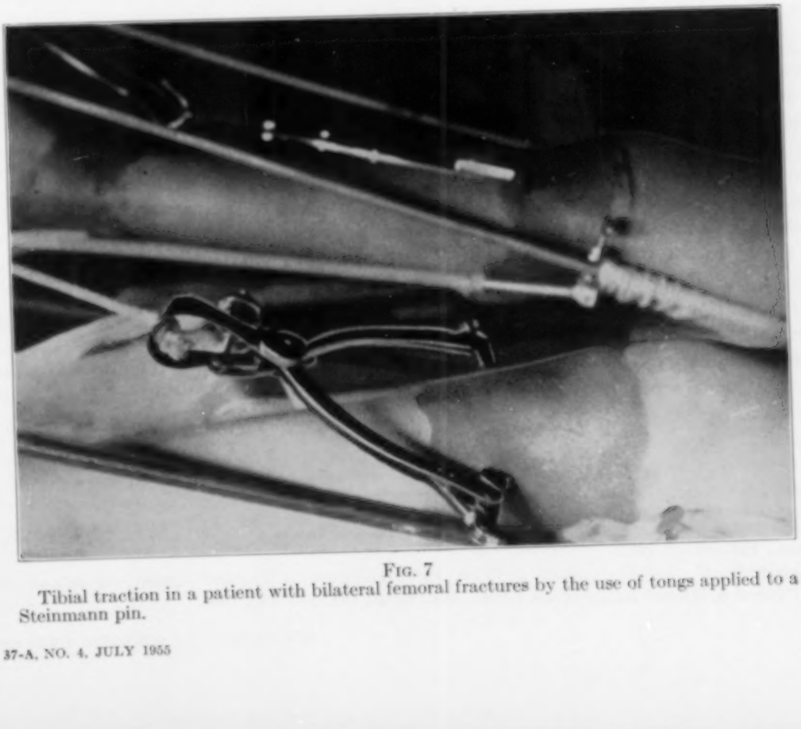

FIG. 7
Tibial traction in a patient with bilateral femoral fractures by the use of tongs applied to a Steinmann pin.

with care to prevent pleural perforation. The points are attached to the rib, and the tongs are tightened. Two to three pounds of pull is obtained by a rope-pulley system attached to the tongs. The wound is closed about the points and dressed. This method controls the lateral paradoxical respiration satisfactorily and lessens the mediastinal displacement. The chief disadvantage of this or any other method used to apply direct traction to a rib is the danger of pleural perforation. This should not be too much of a hazard if the tongs are applied carefully and tightened so that there is no play between the points and the rib. If the patient is irrational and difficult to control, his hands should be restrained to prevent him from pulling out the tongs.

Skull Traction

The tongs are applied to the skull in injuries to the cervical spine in the manner previously described by Crutchfield with minor modifications. After the scalp has been shaved and prepared, lines are painted on the scalp to indicate the mid-line of the skull and the approximate plane of the cervical articulations (through the mastoid tips). The tongs may be fitted with several types of points, but those with the guarded points are preferable (Fig. 4). Under local anaesthesia, stab wounds are made in the scalp, and the skull is penetrated to a depth of four millimeters by a Crutchfield drill. The points of the tongs are then fitted into the skull perforations. A final adjustment of the small side arms is then made, so that the points will be at right angles to the plane of the skull. The adjustability of the side arms is an added advantage of these tongs, as it lessens the danger of slipping. Traction is then initiated by placing a rope through the hole in the metal loop and tying one knot. This procedure gives the advantage of a central balanced pull on the tongs when traction is applied (Fig. 5).

These tongs will accommodate the largest skulls since they expand to a distance of sixteen millimeters from point to point when opened wide. So far, no disadvantages in the use of these tongs for skull traction have been noted clinically. One patient did experience pain about the site of the points, which was due to too tight application of the tongs.

Traction on Long Bones

The tongs have been used in several cases for traction on long bones. In no instance was there any slipping or other complication. A Kirschner wire or, preferably, a Steinmann pin is placed through the long bone in the usual manner and the ends are left approximately 2.5 centimeters long on each side (Fig. 6). The points are removed from the tongs, and the side arms are set parallel with the line of the pin. The hollow ends of the side arms are then fitted over the wire or pin. The Allen screw is tightened until the pin or wire is held fast. The central nut is tightened until the tong arms are spread apart, thus creating tension on the wire or pin which will prevent undue flexibility when the weights are added to the rope-pulley system. The tongs work very well when used for traction through the tibia, but their limitation in width may prevent their use in traction through the femur. For a patient with an unusually large thigh, the tongs have not enough spread to permit their being fixed on the pin or wire; however, traction on the proximal end of the tibia could be used on such an individual quite satisfactorily. Due to the manner in which the side arms fit over the ends of the wire or pin, this method of tong traction is advantageous, since there is little danger of the wire or pin slipping out of the tong arms.

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CROSSED CONGENITAL HEMIHYPERTROPHY

Report of a Case

BY ALVINA O. SABANAS, M.D., ROCHESTER, MINNESOTA,

*Fellow in Orthopaedic Surgery, Mayo Foundation**,

AND C. C. CHATTERTON, M.D., ST. PAUL, MINNESOTA,

Gillette State Hospital for Crippled Children, St. Paul.

Descriptions of congenital hemihypertrophy under such designations as "true hypertrophy", "hemihypertrophy", "hyperplasia", "hemigigantism", "gigantism", "congenital hemicorporal dysharmony", "partial macrosomia", and "megalosomia" illustrate the difficulty in selection and evaluation of cases.

Wagner, in 1839, presented what is probably the first authentic report of hemihypertrophy. Friedberg, in 1867, gave a thorough report on crossed congenital hemihypertrophy of the left upper and right lower extremity. Gesell, in 1921 and again in 1927, reviewed the literature and found, in 1927, a total of fifty-three cases of hemihypertrophy and four cases of crossed hypertrophy. Only one other case of crossed hypertrophy has been reported since that time; this was the case described by Fordyce in 1928.

Since the review by Schwartzman and his associates, in 1942, which included 102 cases, ten cases of hemihypertrophy have been reported[1-4, 9-12, 15, 16]. Our case is the one hundred and thirteenth.

REPORT OF CASE

A white male full-term baby was born spontaneously in December 1935. Immediately after birth the parents noticed the monstrous size and shape of both feet and legs, enlargement of the right ear, and protrusion of the tongue.

The parents had no blood relationship and were healthy. Nobody in the father's or mother's family had any skeletal or cutaneous congenital anomalies. There was no family history of feeble-mindedness.

Two normal babies had been born before this child, and subsequently the mother gave birth to four other normal children. The pregnancy that terminated in the delivery of this child had been entirely normal.

At one and one-half years of age the boy was admitted to Gillette State Hospital for Crippled Children. The right ear was 2.5 centimeters longer than the left and 0.75 centimeter wider. The nares, jaw, and teeth on both sides were equal. The right side of the tongue was greatly hypertrophied.

Lipomata were present in the neck on the right side and on the back of the thorax. In the right posterior axillary line, at the height of the sixth intercostal space, was a telangiectatic area measuring three by five centimeters. An inguinal hernia was present on each side.

The upper extremities were normal. The lower extremities were greatly enlarged in circumference and length; subcutaneous fat was evenly distributed and abundant. Both feet were enlarged. The second and third toes of the right foot were webbed and six toes were present. The second and third toes of the left foot were partly webbed. The size of the feet corresponded to that of a normal child of seven and one-half years of age.

The sixth toe on the right foot was removed, and bilateral herniotomy was performed.

Subsequently, the overgrowth of the lower part of the body from the mammillary line down increased distally until both feet reached pitifully monstrous dimensions. The lower part of the trunk, the pelvis, and the lower extremities appeared to stop growing at about the age of puberty. Since 1949, no great increase in size has been noticed. The patient has worn shoes of the same size since 1949.

Since ten years of age, the boy has been living in a state institution for feeble-minded children. His scholastic ability has never passed that of children in the second grade. The score on the last test for I.Q., at seventeen years of age, was 49.

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* The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

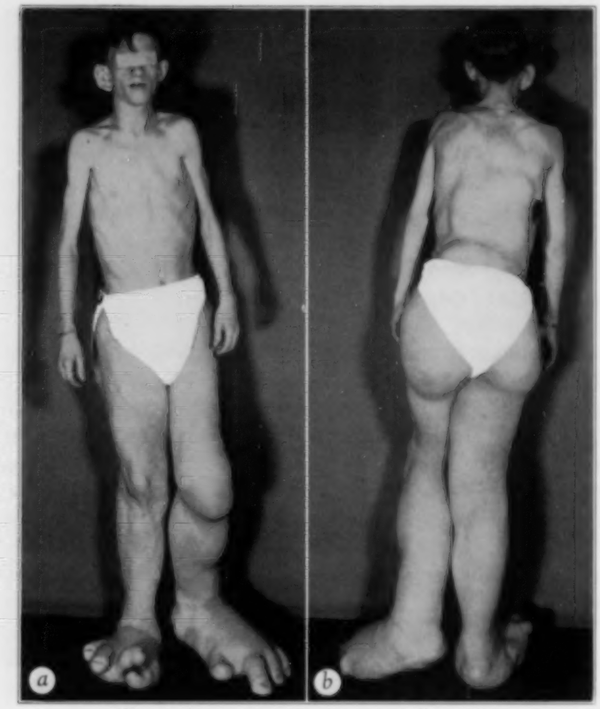
FIG. 1-A FIG. 1-B

Photographs of the patient at seventeen years of age.

In May 1953, at seventeen years of age, the patient was again admitted to Gillette Hospital because the right second and third toes had grown together and were dorsiflexed at an angle of 90 degrees. They rubbed on the shoe and were constantly infected despite the fact that the patient for several years had worn specially fitted shoes. The right shoe corresponds to size 25 and to a width of 70 E, the left to size 27 and width of 75 E.

The condition of the patient on this admission is seen in Figures 1-A and 1-B. He stood with a valgus deformity and flexion of 30 degrees in the left knee and flexion of 30 degrees in the left hip.

A pigmented area, eight by seven centimeters in size, was present on the trunk in the right posterior axillary line. On the back, extending downward from the spinous process of the third thoracic vertebra, the subcutaneous tissue was extremely thick and evenly distributed; this thickening sharply discontinued on both sides at the posterior axillary lines. This lipomatous tissue reached the pelvis and sacrum and joined evenly into overgrown subcutaneous tissue over the gluteal region, thighs, legs, and feet. The lipomatous mass on the back measured forty-one by twenty-one by four centimeters.

The right ear was still longer than the left. Both tonsils were large and pitted, in spite of the fact that the right tonsil had been removed at infancy. The right side of the tongue was greatly enlarged; the tip of the tongue deviated to the left.

Lipomata measuring about seven by seven centimeters were still present in the neck.

Muscle development in the upper extremities was poor. The length of the upper extremities was equal; all joints had a normal range of motion, and some hyperflexibility was present in the metacarpophalangeal joints. On the right side of the abdomen above the symphysis was lipomatous tissue measuring seven by seven centimeters.

Movements in the right lower extremity were free in the hip, knee, and ankle joints. In the left, the motion in the hip joint was free. The knee joint had free flexion, but extension was limited to 120 degrees. The patella was not perceptible in front of the joint.

Roentgenographic survey disclosed normal findings in the skull, vertebral column, thorax, pelvis, and hips, except for the size of the bones in the lower part of the body. The left knee showed subluxation of the femur over the tibia; the patella was dislocated laterally.

Roentgenograms of the feet were made on film of the size normally used in roentgenographic study of the thorax (Figs. 2-A and 2-B). The density of the bones was normal; no spurs, exostoses, or osteochondromata were present. The skeletal age in both feet was the same. The epiphyses were fused. The size and shape of the metatarsals and tarsals were irregular in both feet.

Amputation of both lower extremities was done through the lower third of the thigh. The subcutaneous tissue, muscles, synovial membrane, bone, blood vessels, and popliteal nerves in the amputated extremities were proportionately large.

Dr. Dockerty and Dr. Dahlin, of the Mayo Clinic, examined microscopically the skin, subcutaneous fat, synovial membrane of the knee joints, blood vessels, muscle, and nerve tissue. No abnormalities were found except for some increase in the amount of connective tissue around the nerves.

INCIDENCE

Partial hypertrophy appears to be a more common congenital anomaly than is

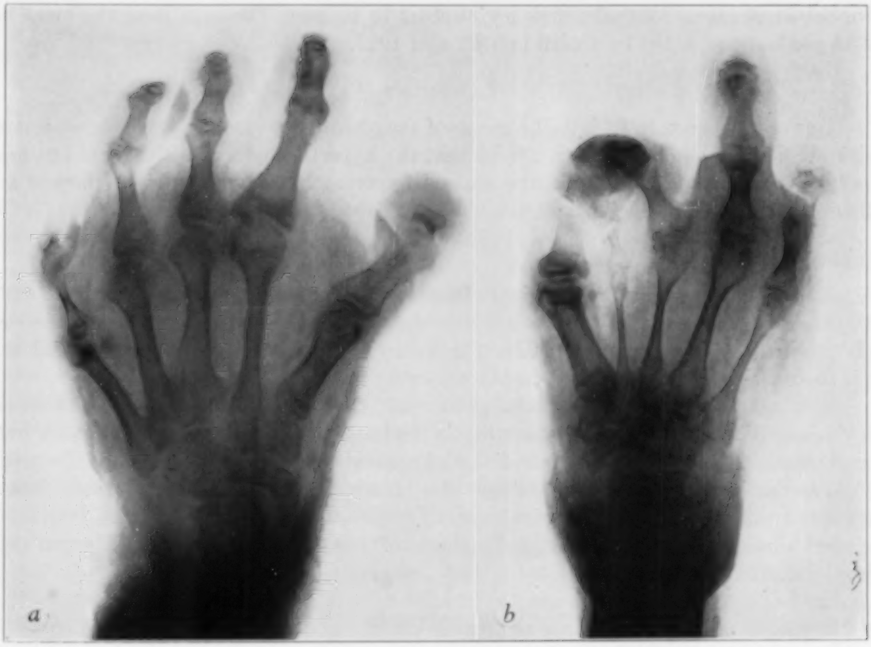

FIG. 2-A FIG. 2-B

Roentgenograms of the left and right feet.

hemihypertrophy; it involves the skeleton and the soft tissues in various parts of the body. It shows a predilection for the extremities, more frequently the lower; it occurs frequently at the distal end of the extremity. Extremities on the left appear to be more frequently involved than those on the right; in the foot the second, third, and first toes are most frequently involved, in that order. Both sexes are about equally represented.

Partial hypertrophy and various types of hemihypertrophy often are associated with the same types of additional congenital anomalies, such as syndactylism, polydactylism, cryptorchidism, multiple lipomata, lymphomata, telangiectasis, vascular and pigmented nevi, abnormal pigmentations, hypertrichosis, and mental deficiency. This association is more frequent with crossed hypertrophy and hemihypertrophy than with partial hypertrophy.

Crossed hypertrophy appears to be a more advanced form of partial hypertrophy because the whole extremity on one side and another extremity on the opposite side, as well as several other organs, are usually involved.

Hemihypertrophy appears to be the next logical step after partial and crossed hypertrophy in this chain of developmental anomalies. In true total hemihypertrophy, one side of the body from the head down to the toes is enlarged; even the hemisphere of the brain on the same side should be larger. Absolutely symmetric hemihypertrophy apparently has not yet been recorded. In all cases more or less asymmetry has been found. Some patients have several organs of normal size on the hypertrophied side, such as the pupil, ear lobe, tonsil, and tongue. Often the hypertrophy appears to reach over to the opposite side of the body in many variations and combinations.

Published necropsy reports have appeared in only ten cases; the reports vary with respect to the size of the brain on the hypertrophied side and the size of paired parenchymal organs, which confirms the absence of any strict rules about the uniformity of hemihypertrophy. Mental deficiency and various cutaneous changes are associated in approximately two thirds of cases. Mental deficiency appears to be more common than the incidence of 15 per cent. reported by Gesell in 1921 and 1927.

COMMENT

Our case appears to fit into the group of congenital hypertrophy typically associated with other congenital anomalies, except that the hypertrophy was not sagittal but horizontal. Additional features were the crossed hypertrophy above the right clavicle and the lipoma in the mid-line of the back.

Etiology

The actual cause and mechanism of congenital partial hypertrophy, crossed hypertrophy, or hemihypertrophy have not been established. The twinning theory has been advanced to explain these anomalies, particularly by Gesell; it is now considered that this theory is inadequate to explain many cases.

A combination of faulty parental genes could presumably cause such developmental deviations. The rarity of the abnormality indicates that, if it is at all hereditary, it must be of the recessive type. It is not sex-linked, because both sexes are affected about equally.

Studies in experimental teratology offer convincing evidence that extrinsic factors are able to produce anomalous growth of different organs, especially if these factors are applied during the "critical stages" (times of rapid differentiation and growth) of development.

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AN EFFECTIVE AND COMFORTABLE CERVICAL BRACE

BY JOHN G. MCNAMARA, M.D., AND WILLIAM WAGENSEIL, BROOKLYN, NEW YORK

Because of the obvious discomfort of the braces usually employed in the treatment of cervical lesions and because of the widespread dissatisfaction voiced by patients who have had to use them, the authors, after considerable experimentation, have devised a prosthesis which they consider furnishes both adequate immobilization and a much greater amount of comfort. This brace has been most successful in the conservative treatment of cervical arthritis, herniated discs, luxations, and in postoperative immobilization of patients with fusions of the cervical vertebrae, after removal of the initial plaster cast. By eliminating mandibular pressure—which is so obnoxious to many patients, especially those wearing dentures—and by substituting control at the occipital, parietal, and frontal regions, we have made a brace which provides adequate restriction and at the same time allows the wearer greater freedom and comfort. With this brace, patients have had no difficulty in sleeping, eating, washing, or shaving; women patients have been able to conceal the brace, after removing the chin strap, by wearing a kerchief and by so doing go outdoors without feeling too conspicuous.

As shown in the illustrations, the basic part of the brace is a longitudinal thoracocervical bar. The cervical portion (*A*) divides, and projections extend forward and upward along the parietal areas to end at each temple. This bar is made from one-half-inch to one-eighth-inch surgical steel, and the extensions which support the head are covered by calfskin lined with horsehide. At the end of each of the "cowhorn" projections is a small stud, providing attachments for the frontal strap (*B*) and the chin strap (*C*).

In order to prevent tampering, we have sometimes found it necessary, when dealing with young children or somewhat incorrigible patients, to substitute for the frontal strap a forehead bar of the same metal, adequately lined. This bar is attached to one cowhorn projection by a hinge and is so adjusted as to fit into the other by a snap catch. This contrivance, however, is seldom necessary.

The thoracic portion is a somewhat shortened version of a Taylor-type spinal brace. It is made from one half-inch by one-eighth-inch duralumin and covered with calfskin lined with horsehide. Incorporated in it is a bridge (*D*), which is reamed to accommodate an eight-thirty-seconds-inch screw for the attachment of the thoracic portion of the longitudinal bar (which has been reamed at intervals, thus allowing for minor adjustments without removal).

Straps of webbing and buckles are then attached to the upper (*E*) and lower (*F*) parts of the thoracic brace to complete the assembly.

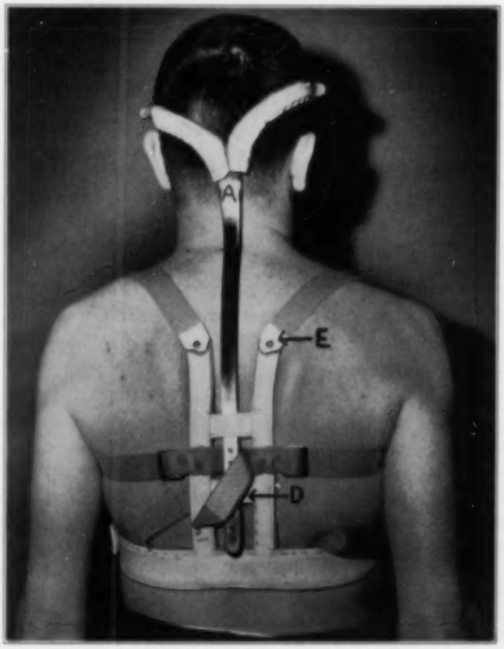

Fig. 1

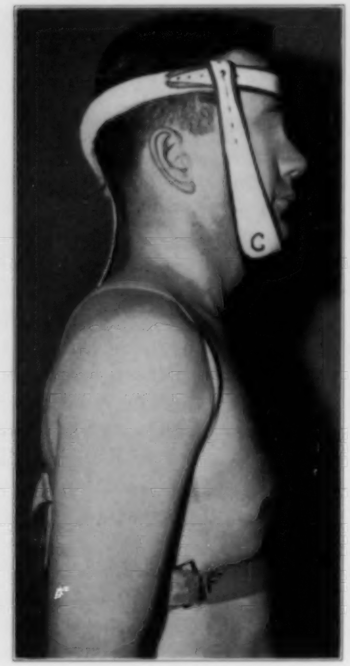

Fig. 2

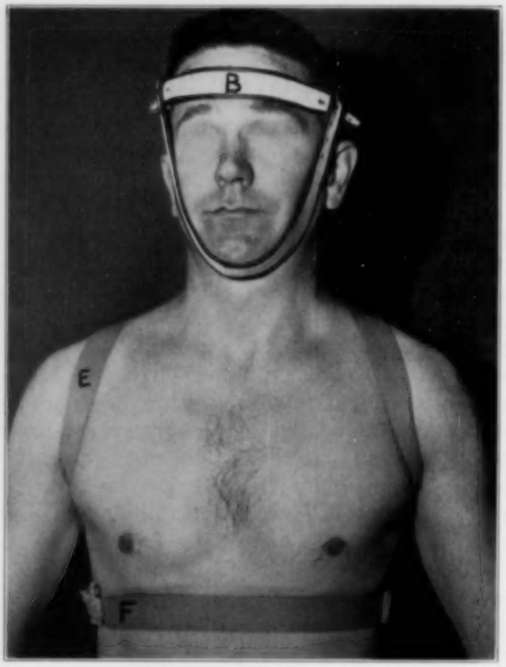

Fig. 3

It is a simple matter, if one so desires, to modify the lower portion and extend it distally to the pelvis, thus combining a Taylor spinal brace with a cervical brace.

FRACTURE OF THE FABELLA

Report of a Case

BY BERNARD S. LEVOWITZ, M.D., AND HAROLD D. KLETSCHKA, M.D., BROOKLYN, NEW YORK

From the Department of Surgery, State University of New York, State University Medical Center at New York City, and Kings County Hospital, Brooklyn

Fracture of the fabella is rare. The authors found only one other case, reported by Sagel[1], in a patient who sustained an intercondylar fracture of the femur with a stellate fracture of the fabella. The following case presentation describes an isolated fracture of this sesamoid.

Case 50957. The patient, E. R., was a counterman, thirty-one years old, who was admitted to this institution, Kings County Hospital, November 6, 1953, with a history of having been struck from behind by a car. He had been pushed forward in such a way that his knees hit another car in front of him.

Positive clinical findings were limited to the lower extremities. The left knee was swollen and tender to pressure, particularly on the medial aspect. There was no evidence of joint instability. Passive and active movements of the right knee elicited slight pain. There was an abrasion below the right knee. Peripheral pulses in both lower extremities were satisfactory.

Roentgenographic examination revealed a fracture through the left fabella with slight displacement (Figs. 1-A and 1-B). Roentgenograms of the right knee showed no fracture; a fabella was present on this side also (Fig. 2).

The diagnosis at this time was of a fracture of the left fabella with an associated hemarthrosis of the left knee.

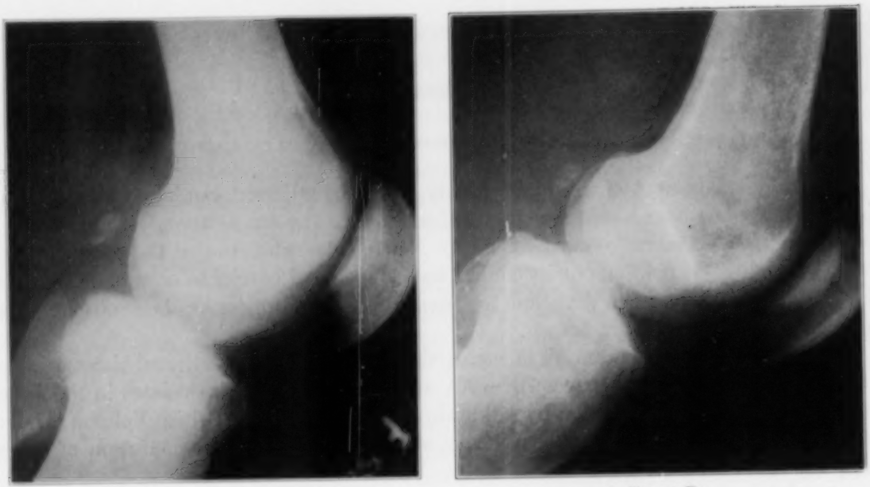

FIG. 1-A FIG. 1-B

Fig. 1-A: Oblique roentgenogram of the left knee, demonstrating fracture of the fabella with slight displacement.

Fig. 1-B: Lateral roentgenogram of the left knee, showing linear fracture traversing fabella.

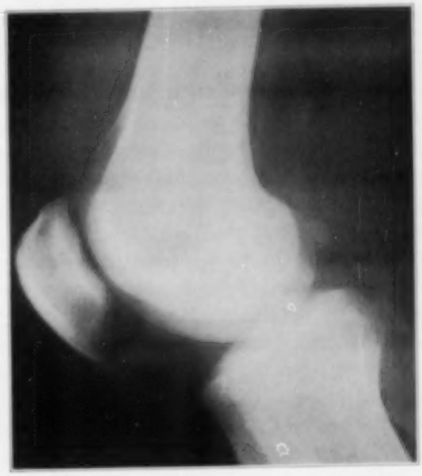

FIG. 2

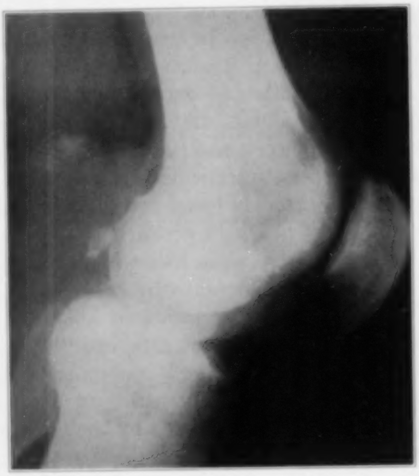

FIG. 3

Fig. 2: Lateral roentgenogram of right knee, showing a normal fabella.

Fig. 3: Lateral roentgenogram of the left knee, showing the healed fracture of the left fabella.

The left knee joint was aspirated on two successive days following admission to the Hospital, and on both occasions twenty cubic centimeters of bloody synovial fluid was obtained. The left lower extremity was temporarily immobilized in mild flexion in a posterior molded splint from toes to groin with a pressure dressing over the knee. On the third hospital day, the patient was discharged to the Out-Patient Clinic on crutches.

After six weeks of ambulation on crutches without bearing weight on the left lower extremity, the patient was gradually restored to full activity. An examination made eight weeks after injury revealed no limitation of motion and painless weight-bearing. Roentgenograms of the left knee at this time showed a completely healed fracture of the fabella (Fig. 3).

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EDITORIAL

SPONDYLOLISTHESIS

Ventral displacement of a vertebral body upon the adjacent caudal segment of the spine was described over a century ago by Rokitansky. The term "spondylolisthesis" — that is, "slipped vertebra" — was coined by Neugebauer who studied the entity intensively. Kilian in 1854 pointed out its clinical importance as a barrier to normal delivery in the obstetrical patient. Since that time the literature on the subject has become extensive and in many instances contradictory.

A critical comparative analysis of such articles as that by Bosworth and his associates in this issue of *The Journal* (pages 767–786), that by Gill and his associates in the June number (**37-A**: 493–520), and that by Adkins in a recent issue of the British Volume (**37-B**: 48–62, Feb. 1955) illustrates the complexity of the problem and the confusion of ideas which now exist.

Spondylolisthesis, as pointed out by Macnab, may occur in the presence of an intact neural arch, but in the usual case there is a bilateral defect in the neural arch of the involved vertebra at the pars interarticularis. This results in a bipartite vertebra, in which the spinous process, laminae, and inferior articular processes form one osseous unit, while the vertebral body, transverse processes, pedicles, and superior articular processes form the other unit which slips forward, leaving the neural arch behind. The two parts are joined only by a fibrocartilaginous mass of soft tissue.

Spondylolisthesis occurs in about 5 per cent. of the adult population, but its presence has never been demonstrated in examination of numerous foetal specimens. For this reason, both Hitchcock and Batts concluded that the theory of congenital defective ossification of the pars interarticularis is untenable. They were also unable to find the anomalous ossification centers in foetal neural arches which other investigators described as a probable important factor in producing the hypothetical congenital malformation.

Hitchcock has shown that bilateral fractures through the pars interarticularis may be produced experimentally by hyperflexion "with little force" of the lumbar spine of the stillborn child. He also produced unilateral fractures by combining lateral bending and torsion with flexion. Thus experimental data and theoretical consideration suggest that the defect in the neural arch is not a congenital malformation but may be due to fracture of the intact neural arch occurring during or shortly after birth. It has also been suggested that a shearing force imposed by the body weight in the erect position may induce stress fracture of the pars interarticularis in the young child. Careful comparative examination of the spines of a suitable number of foetuses, infants, and young children would cast light on the problem of the etiology of spondylolisthesis.

Present knowledge indicates that the osseous defect in the neural arch, spondyloschisis, is not present in foetal life, but appears in the newborn, or in early childhood. At first there is no displacement of the vertebral body, but with the passage of time a variable amount of forward slip of the involved vertebra on the one caudal to it occurs, with widening of the defect in the pars interarticularis and with gross change in the shape of the neural canal, to which the dural sac and the roots of the cauda equina must adapt themselves.

Arrest of the slipping process and relative stability may occur at any age. Bosworth suggests that the involved neural arch, which at operation is so mobile, may in fact help to block further anterior displacement of the vertebral body. He has noted that further slip of the vertebral body may occur after operative removal of the defective neural arch.

It is difficult to ascertain the factor or factors which give rise to clinical symptoms in spondylolisthesis, for many individuals have no symptoms attributable to its presence and there appears to be no correlation between the amount of vertebral displacement and the symptoms. Back pain, when present, is usually intermittent and is related to posture and physical activity. This pain is presumed by most investigators to be due to ligamentous or apophyseal joint strain. It is, therefore, commonly treated by conservative measures,—such as postural exercises, low-back supports, use of a firm mattress, and restriction of physical activities. Such measures may suffice for mild cases, but the more severe cases are unrelieved, and in these patients symptomatic cures are not to be expected from non-operative treatment.

On the premise that a soundly fused joint is a painless joint, arthrodesis of the spine has become the accepted surgical treatment for low-back pain caused by spondylolisthesis. However, sound fusion is not easily attained, and there are verified instances in which intractable pain, radiating into the lower extremities, developed after successful arthrodesis.

Adkins and Gill have found in their patients clinical evidence of radiculitis involving the fifth lumbar and first sacral roots and have demonstrated at operation that the nerve roots may be irritated or compressed by the fibrocartilaginous mass which fills the osseous defect in the neural arch. In some instances, a free ossicle may be present in the fibrocartilaginous mass, impinging on the nerve root from the posterolateral wall of the foramen. There are other, less frequent causes of root irritation, such as accompanying disc protrusions and narrowing of the intervertebral foramina. Occasionally the dura may be stretched over the posterior rim of the body of the sacrum or compressed by the laminae of the vertebra immediately cephalad to the lesion.

Gill and his associates reported a small series of cases treated by removal of the loose neural arch and by careful nerve-root decompression without fusion. Adkins advised a similar decompression operation but added posterior rhizotomy and fusion to the procedure. Bosworth advises fusion without decompression.

The combined operation of exploration, root decompression, and spine fusion requires considerable surgical skill and is a relatively formidable procedure. For this reason, the alternative procedures of arthrodesis without decompression or of decompression without arthrodesis will be chosen by many surgeons.

There is a relatively high rate of failure of fusion in attempted arthrodesis, and we await the development of a standard technique which will be uniformly successful. Although the decompression operation described by Gill is attractive because of its relative simplicity, the cautious surgeon will await long-term end results, remembering that perineural fibrosis or further slip of the vertebral body may produce recurrence of symptoms. That same cautious surgeon will hesitate to fuse the spine without making certain by direct inspection that the nerve roots are free from abnormal pressure.

The confusion and conflicting opinions abounding in the literature on spondylolisthesis are evidence that medicine is still as much an art as it is a science and that all investigators are beset with the pitfalls of inaccurate observation, inadequate data, and *post hoc* deduction.

The doctor's dilemma, in the case of spondylolisthesis, is a serious one.

J. S. Barr, M.D.

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CORRECTION

An error appears in the summary of the paper by Dr. E. L. Billing, "Congenital Scoliosis: An Analytical Study of Its Natural History" on line 1, page 405, in the Proceedings section of the April 1955 issue of *The Journal*. For the sentence to be correct, the word "not" must be inserted between the words "are" and "severe". The line will then read:

1. Lateral curvatures resulting from a single hemivertebra are not severe, usually being less than 45 degrees.

CORRECTION

In the summary of the paper by Dr. H. Relton McCarroll, *Congenital Dislocation of the Hip*, presented at the Annual Scientific Meeting of the Alumni of the Hospital for Joint Diseases, two errors appeared. This summary was published in Proceedings of the April 1955 issue of *The Journal*.

On page 418, paragraph 5, line 5, the sentence beginning: "In patients with frank dislocation . . ." would express more accurately Dr. McCarroll's meaning if it were changed to read: "In patients with frank dislocation, whose femora cannot be lifted into position without force and without trauma . . ."

In the same paragraph, line 9, the sentence: "The hips are maintained in the frog-leg position . . ." would express Dr. McCarroll's meaning more accurately if changed to read: "The hips of patients on whom preliminary skeletal traction is used are maintained in a position of abduction and internal rotation. The frog-leg position is used only in those children in early infancy whose normal resting position is one of flexion at the hip joint."

HAROLD HOMER HITCHCOCK

1893–1955

Dr. Harold Homer Hitchcock died in Oakland, California, on February 6, 1955. His sudden passing was an overwhelming shock to his patients, friends, associates, and students.

"Hitch", as he was affectionately known to his friends, was born in Tulare, California, on June 16, 1893. He attended the University of California where he obtained a Bachelor of Arts degree, *cum laude,* in anatomy in 1915 and the degree of Doctor of Medicine in 1918. His postgraduate training consisted of an internship and assistant residency in medicine and an assistant residency in orthopaedic surgery at the University of California Hospital. This was followed by a house officership at the Children's Hospital and the Massachusetts General Hospital in Boston. In his years in medicine at the University of California Hospital, this promising young man was closely associated with Dr. Herbert C. Moffitt, one of our greatest teachers and clinicians.

Dr. Hitchcock commenced his practice in orthopaedic surgery in Oakland, California, in 1922. Shortly thereafter, he became head of the Orthopaedic Services of the Alameda County Hospital, the Fabiola Hospital, and the Cowell Memorial Hospital; later, he became the Chief of the Orthopaedic Service at the Samuel Merritt Hospital and Senior Consultant in Orthopaedic Surgery at the Cowell Memorial Hospital. It was at this latter institution that he acquired his wide experience in the diagnosis and treatment of athletic injuries and gained recognition as an outstanding authority in this special field. Under his direction, the Orthopaedic Service at the Samuel Merritt Hospital was integrated with the graduate training program at the University of California School of Medicine.

Dr. Hitchcock was a man of great natural talent. He possessed a keen intellect, a thorough knowledge of anatomy, and unusual surgical ability. He was at his best when teaching small groups of men whom he inspired to their best endeavor. He was not a prolific writer, but the value of his writings was in their merit rather than in their volume. His outstanding contributions were on spondylolisthesis, calcium deposits about the shoulder, and the painful shoulder.

He was a member of Alpha Omega Alpha, Beta Kappa Alpha, and Sigma Xi, and held memberships in The American Orthopaedic Association (he served as Vice-President in 1952), The American Academy of Orthopaedic Surgeons, American Medical Association, Western Orthopedic Association, Pacific Coast Surgical Association, Robert Jones Orthopaedic Club, California Medical Association, California Academy of Medicine, and the Alameda-Contra Costa Medical Association.

Hitch loved the out-of-doors and was in his glory while entertaining a group of his intimate friends at his ranch in Cloverdale. He prepared food as only a gourmet could—whether in the kitchen, over the barbecue pit, or over a Chinese brazier. He was proud of his vineyards and the rare wines which were aged on his premises. In his gardens he "loved to watch things grow". Last, but not least, he was an able fisherman, and a day on the stream with him was always to be remembered.

Hitch is lost to us in person, but his memory will long be vital, as he was vital, and we will be lifted by his genius while yet we live. As one of his colleagues remarked, "We will miss his professional skill, his ability to teach, but most of all the soul of the real man, who inspired everyone with whom he came in contact".

LeRoy C. Abbott

LEE C. SCHLESINGER

1912–1954

Dr. Lee C. Schlesinger died June 27, 1954, after an illness of almost a year. An untiring and unselfish worker in the field of orthopaedic surgery, he was particularly interested in the treatment of cerebral palsy. He was largely responsible for the establishment of the Cerebral Palsy Center for Greater New Orleans, serving as its Medical Director from the time of its inception in 1951 until his death. Although he was only forty-two years of age at the time of his death, his achievements in the field of orthopaedic surgery were many and varied. An accomplished speaker, Dr. Schlesinger was extremely popular with the undergraduate students at Tulane University. His patience and kindness in the training and teaching of orthopaedic residents will long be remembered by those who, during their orthopaedic training period, came under his influence.

A native of Memphis, Tennessee, he was born on March 28, 1912. He was graduated from Central High School in Memphis and from Vanderbilt University. He received the degree of Doctor of Medicine in 1935 from the University of Tennessee School of Medicine. He served his internship at Touro Infirmary in New Orleans in 1935 and 1936 and was Surgical Resident in the same institution from 1936 through 1938. From 1940 to 1942, he completed his orthopaedic training as a resident on the Tulane University Orthopaedic Service at Charity Hospital. Immediately following completion of his orthopaedic residency, he entered active military service, serving in the Army Medical Corps during World War II until 1945, when he returned to private practice in New Orleans.

In 1938, Shirley Latter of New Orleans became his wife. Two children were born, Lee H. and Lisa Ann.

Dr. Schlesinger was active in many orthopaedic and surgical societies. His membership in The American Academy of Orthopaedic Surgeons dates back to 1948 and he served as Junior Member of the Executive Committee for the year 1952. He was a Fellow of the American College of Surgeons and of the International College of Surgeons, and a member of the Association of Bone and Joint Surgeons, American Academy of Cerebral Palsy, Southeastern Surgical Congress, and American Medical Association, as well as of the local, state, and regional medical societies. He was Assistant Professor of Clinical Orthopaedics at Tulane University School of Medicine, Senior Visiting Orthopaedic Surgeon at the Charity Hospital in New Orleans, and Senior Orthopaedic Surgeon at Touro Infirmary and Flint-Goodridge Hospital. He was Orthopaedic

PHOTOGRAPH BY FABIAN BACHRACH

LEE C. SCHLESINGER

Consultant to the Crippled Children's Division, Louisiana State Department of Health, and Consulting Orthopaedic Surgeon of the Louisville and Nashville Railroad. He also served for several years as Attending Orthopaedic Surgeon at the Veterans Administration Hospital in New Orleans.

His interest in the care of cerebral-palsied patients led him to do extensive postgraduate work in this field, and he devoted much of his time to this problem. He had the happy faculty of being able to secure the maximum cooperation between the professional and non-professional workers in this field and was able to iron out many of the difficulties which are encountered in establishing a center of this kind.

As a member of the Advisory Committee of the Crippled Children's Hospital, Dr. Schlesinger was active in raising funds for this institution. It is unfortunate that he was unable to witness, in March of this year, the dedication of this beautiful institution, a large part of which was accomplished by his untiring efforts.

Dr. Schlesinger will be long remembered by his confreres and associates as a top-flight orthopaedic surgeon, a devoted husband and father, an inspiring teacher, and fundamentally a doctor beloved by his patients and one who considered their welfare foremost.

Harry D. Morris

Proceedings

THE PIEDMONT ORTHOPAEDIC SOCIETY

As Reported by Robert A. Knight, M.D., Memphis, Tennessee

The Piedmont Orthopaedic Society, comprised of orthopaedic surgeons who have received their training through the Duke Orthopaedic Training Program, held its Fifth Annual Meeting at the Bowman Gray School of Medicine, Winston-Salem, North Carolina, April 1 and 2, 1955, under the presidency of Dr. Cabell Young, Jr., Winston-Salem.

The first day's scientific program was presented by members of the faculty of the Bowman Gray School of Medicine.

Spinal Fusion for Fracture-Dislocation of the Cervical Spine. Dr. H. F. Forsyth discussed spine fusion for fracture-dislocation of the cervical spine in fifty patients who were treated at the North Carolina Baptist Hospital between January 1948 and January 1955. Over half of these patients showed neurological changes on admission. The less severely injured were treated with traction, cervical-spine braces, or Minerva plaster jackets, while the more severely injured were treated with skeletal traction, followed by hemilaminectomy, open reduction, and cervical-spine fusion with internal fixation according to the Rogers technique. The time in bed, the period of hospitalization, and the loss of time from work were materially reduced by early fusion. Fusion permits ambulation in a light cervical-spine brace rather than a Minerva plaster jacket. There is also less residual or recurrent deformity, greater stability, and less pain following open reduction and fusion. Postoperative complications were rare in this series. Dr. Forsyth stressed the importance of preparing the bony bed for fusion by "nibbling" the laminae and spinous processes with a rongeur rather than by pounding upon the posterior spinal elements with an osteotome and mallet. In fractures of the odontoid process, the upper three cervical vertebrae are fused without incorporating the occiput; in the lower cervical spine, circumferential wiring of the spinous processes, with the addition of iliac-bone grafts or bank-bone grafts, is employed.

Hyperextension Injuries of the Cervical Spine. Dr. Eben Alexander, Jr., related that Taylor and Blackwood[a], in 1947, and Taylor[b], in 1951, demonstrated by clinical and autopsy studies that marked hyperextension of the cervical spine, particularly in those patients with degenerative arthritis and spurs on the dorsal surface of the vertebral bodies, may rupture or tear the anterior longitudinal ligament and produce an actual contusion and laceration of the spinal cord. The ventral surfaces of the laminae, and probably of the ligamentum flavum as well, compress the dorsum of the cord, while the ventral surface of the cord is compressed by the bony spurs. This is well demonstrated by roentgenographic studies on the cadaver. In Dr. Alexander's repetition of the work of Taylor and Blackwood, pantopaque was introduced at the level of the second thoracic vertebra in the cadaver. A horizontal-beam lateral roentgenogram revealed that the column of pantopaque was not indented significantly in the neutral position, but that, in the position of hyperextension, a prominent indentation took place, particularly from the dorsal surface, which may reduce the diameter of the cervical spinal canal as much as 50 per cent. or more. When the neck was again flexed, no bony change was apparent. Postmortem examination in a few instances had demonstrated that the local spinal-cord injury was most severe in its central portion, there being hemorrhage and necrosis. In an injury at the fifth cervical level, the paralysis and, needless to say, the rehabilitation of the patients are serious and discouraging problems, particularly in elderly patients. Disability usually persists longest in the arms, for the long tracts of the upper cervical region are located medial to those of the legs and body.

Protrusions of the cervical-intervertebral-disc material may occasionally occur following hyperextension injuries; in these cases, a spinal-fluid block may be present. In some instances, the myelographic defect may be so large that decompression of the cord is necessary. The spectrum of injuries of this sort will vary from a sharp hyperextension injury, which is followed by headache and pain in the neck, but is not accompanied by neurological signs, to the very serious injury after which the patient is disabled with a complete or almost complete tetraplegia. The medical, legal, and liability problems are great; in the country as a whole, as much as 15 to 20 per cent. of all liability cases due to automobile accidents are the result of this particular injury. Efforts are being made by the American Academy of Neurological Surgeons and the American College of Surgeons to incorporate safety devices in automobiles, including apparatus to prevent hyperextension injuries to the neck when the vehicle is struck forcibly from behind.

[a] Taylor, A. R., and Blackwood, William: Paraplegia in Hyperextension Cervical Injuries with Normal Radiographic Appearances. J. Bone and Joint Surg., **30-B**: 245–248, May 1948.

[b] Taylor, A. R.: The Mechanism of Injury to the Spinal Cord in the Neck without Damage to the Vertebral Column. J. Bone and Joint Surg., **33-B**: 543–547, Nov. 1951.

The Other Problems in Cerebral Palsy. Dr. C. H. Davis, Jr., pointed out that the efforts of lay groups and most physicians have been devoted to the active rehabilitation of the cerebral-palsied patients with minimal mental and moderate physical handicaps. Although these patients warrant all efforts in their behalf, the fact remains that only about one fourth of the cerebral-palsied patients can be rehabilitated to be self-sustaining. Insufficient emphasis has been placed upon those patients who cannot be rehabilitated and upon the predicament of their families. The recommendation to "put the child away and forget about it" may not be the best advice at the time, even though institutional facilities may be available. Rehabilitation of the family and maturation of the normal siblings may be delayed or may not be accomplished at all because of complex emotional problems and the lack of understanding between the family and the physician. In order to attain maximum rehabilitation of the family and maximum return for cost, integrated personal education and community education must be fostered by the physician in view of "the other problems in cerebral palsy".

Some Physiological and Pharmacological Principles of General Anaesthesia for the Adult Orthopaedic Patient. Dr. D. LeRoy Crandell pointed out that there are now a variety of controllable drugs available for use. The safe administration of an anaesthesic requires that these drugs be used according to basic pharmacological principles.

The anaesthetic state consists of three major components: hypnosis, analgesia, and muscular relaxation. By the judicious combination of thiopental sodium or thiamylal sodium for hypnosis and nitrous oxide, supplemented by a demerol drip for analgesia and a succinylcholine drip for muscular relaxation, a non-explosive physiological state of anaesthesia may be produced in the orthopaedic patient without interfering with vital respiratory and cardiovascular mechanisms. The use of thiopental sodium or thiamylal sodium alone to produce anaesthesia will produce a state of acute barbiturate poisoning differing only in its duration from the acute barbiturate poisoning seen from suicidal attempts with the short-acting and long-acting barbiturate drugs.

By the intelligent application of basic pharmacological and physiological principles, anaesthesia can be made safer for the patient and more convenient for the surgeon.

On the Origin, Development, and Classification of Tumors of Bone. Dr. Robert P. Morehead presented his concepts of bone tumors. He pointed out that the difference between a true neoplasm and a benign hyperplasia is that, in the former, there is a continued growth after the removal of the initial stimulus.

The majority of tumors are composed of cells of a single type and must be considered separately from hamartomata and teratomata.

His histogenetic classification was then presented and discussed.

Steroid Therapy in Orthopaedic Surgery. Dr. Ernest Yount indicated that the primary action of the adrenal steroids utilized in therapy is the "anti-inflammatory" effect. This action aids in the prevention of local tissue damage and bacterial infections; however, under some conditions, the host response may be sufficiently altered to encourage widespread dissemination of the organisms. The danger of peptic ulceration and the relative adrenal atrophy which may follow long-term steroid therapy were emphasized.

Disseminated Lesions of Bone. Dr. J. F. Martin showed a series of roentgenograms demonstrating disseminated lesions of bone in leukaemia, lymphosarcoma, eosinophilic granuloma, and metastatic neuroblastoma and retinoblastoma. An unusual response of a destructive leukaemic lesion to aminopterin, with complete restoration of normal bone architecture, was demonstrated. Since the majority of these diseases produce bone destruction and periosteal reaction, a specific roentgenographic diagnosis cannot usually be made. Thus, other features of these diseases must be observed in order to make a specific diagnosis.

The program of the second day was comprised of papers presented by members of the Society.

Modifications of the Hemipelvectomy Procedure. Dr. Kearns Thompson[1] presented a colored motion picture of a hemipelvectomy procedure. The operation was performed for metastatic squamous-cell carcinoma of the trochanteric region of the hip, secondary to an old marginal ulcer which had developed in a burn sustained twenty-three years previously. The patient was operated upon in the lateral decubitus, with two teams operating simultaneously according to the technique of Sorondo-Ferré. The hypogastric artery was occluded temporarily. The iliac artery was ligated initially, and the femoral vein later, after the blood had drained from the suspended limb.

Volkmann's Contracture. Dr. J. L. Goldner[2] discussed his experiences in the surgical treatment of fourteen patients. He pointed out that early decompression of the median nerve may relieve pain within twenty-four hours and may be followed by return of function in some of the intrinsic muscles of the hand.

[1] 288 South Limestone Street, Lexington, Kentucky.

[2] Duke University Hospital, Durham, North Carolina.

This has been likened to the release of an "internal tourniquet". The nerve, upon examination, frequently shows evidence of ischaemia, secondary to compression by the pronator teres and the muscle mass of the flexor digitorum sublimis. Tenotomy and myotomy, with extensive local excision of non-viable tissue, can be performed without sacrificing function. Tendon transfers may be performed later, even in the young child, to improve finger flexion and opposition of the thumb. The wrist extensors are transferred into the tendons of the flexor digitorum profundus muscles, and the tendon of the extensor carpi ulnaris is used as the motor for an "opponensplasty". In the severe wrist-flexion deformity of long standing, partial or complete carpectomy is useful; the procedure may be performed in conjunction with tendon transfers and arthrodesis of the metacarpophalangeal joint of the thumb. Should mobilization of the thumb be desirable, the greater multangular bone may be excised.

Giant-Cell Tumor of the Second Cervical Vertebra. Dr. Leslie C. Meyer [3] reported the case of a giant-cell tumor involving the second cervical vertebra in a young adult female. Biopsy was performed through the transpharyngeal route. Deep roentgen-ray therapy failed to afford improvement or even to slow the progress of the tumor. Despite an occipitocervical fusion, the tumor spread from the second to the third cervical vertebra, and, when last examined, the patient was becoming quadriplegic. It is quite probable that the tumor has undergone malignant degeneration.

Punch Biopsies as an Adjunct to the Diagnosis of Arthritis. Dr. John P. Adams [4] reported that punch biopsy of the knee, performed according to the Bickel-Polley method, has been successfully employed in a series of twenty patients at the George Washington University Hospital. Xylocaine anaesthesia was used for its local and topical effects. In cases in which no effusion is present, saline or xylocaine is injected into the synovial membrane of the region of the suprapatellar pouch in order to facilitate the removal of the synovial specimen by the punch. Considerable pressure must be exerted by the hand in order to press the synovium into the slot in the biopsy punch.

Total Patellectomy. Dr. W. A. Hoyt, Jr.,[5] discussed the indications for total patellectomy, particularly in the patient with chondromalacia patellae. The anatomy of the quadriceps mechanism and the mechanics of the knee extension were considered. Pointing out that a simple overlapping procedure is insufficient to restore full strong extension of the knee, Dr. Hoyt advocated a more elaborate criss-cross overlapping flap in repair of the defect following patellectomy. In his hands, this has resulted in more nearly normal function of the knee joint. A cylinder cast is worn for at least three weeks after operation.

Complications and Errors in Medullary Nailing of the Femur. Dr. Robert A. Knight [6] discussed both the common and the rare complications and errors of medullary nailing of the femur. The procedure is not without its "traps", and, in cases in which the operation is to be performed, the surgeon must minimize difficulties and complications by adequate preoperative planning and by employing the procedure only upon proper candidates and under optimal operating conditions.

Thirty-Year Follow-up Case Report of X-Ray Therapy to the Hip Region in Childhood. Dr. John B. Feltner [7] reported a patient to whom, at the age of two, roentgen therapy of an unknown amount was administered for an unknown condition involving the hip region. A keloid scar, overlying the same hip laterally, had been excised when the patient was thirteen. Hypertrophic degenerative changes were present in the hip; there was hemiatrophy of the pelvis, and atrophy and shortening of the femur. A painful destructive lesion developed in the trochanteric region of the femur; biopsy tissue revealed the presence of an osteogenic sarcoma. Despite hemipelvectomy, death occurred within two years as a result of multiple pulmonary metastases. The late effects of radium poisoning, as well as of radiation therapy, were then discussed.

A Perplexing Parosteal Tumor. Dr. F. Wayne Lee [8] reported the development of a parosteal osteogenic sarcoma of the tibial shaft in a five-year-old male. The tumor was widely resected, and the defect was bridged by a bone graft from the opposite tibia. Long-term follow-up is not yet available.

Juvenile Lumbar Kyphosis. Dr. Darius Flinchum [9] discussed this rather unusual condition, reporting nine patients in whom it was present. The wedging involved, primarily, two or three vertebrae, usually at the thoracolumbar junction. Joint narrowing and bone adaptation occurred; the thoracic spine became flattened secondarily. The lesion is believed to be an osteochondritis. It is possible that a local spine fusion might be indicated in younger individuals in whom the deformity is severe and in the older patients who have disabling symptoms unrelieved by back support.

[3] 9–11 Medical Court, Greenville, South Carolina.
[4] 1703 Rhode Island Avenue, N. W., Washington 6, D. C.
[5] 666 West Market Street, Akron 3, Ohio.
[6] 869 Madison Avenue, Memphis 3, Tennessee.
[7] 700 Main Street, W., Rochester, New York.
[8] 1012 Kings Drive, Charlotte, North Carolina.
[9] 1316 13th Avenue, Columbus, Georgia.

Experiments with Heterogenous Bone Grafts as an Adjunct to the Bone Bank. **DR. CABELL YOUNG, JR.**,[10] pointed out that heterogenous bone may be used as a source of bone-graft material with a fair degree of assurance that it will be incorporated in the host. The protein matrix of bone has but little effect in inhibiting bone formation, and therefore does not, in all probability, require removal. On the other hand, the presence of fat is a definite deterrent to osteogenesis.

In rather extensive experimental procedures and limited clinical experience with this method, cancellous beef bone, cut into one-eighth-inch cubes, was used. The bone is prepared as follows: the diced fresh bone is placed in distilled water for twenty-four hours to hemolyze the blood elements; the bone is then placed in absolute alcohol for twenty-four hours to begin extraction of the fat and to dehydrate the bone. Next, the bone is placed in ether for forty-eight hours, the ether being changed after twenty-four hours. The ether is then decanted; the bone is exposed to air until evaporation of the ether is complete, and then it is stored in an unsterile Erlenmeyer flask. At the time of operation, the bone is autoclaved in saline for twenty minutes.

Experimental grafting studies revealed definite incorporation of the heterogenous beef bone into the host bed, although at a significantly delayed rate as compared with the speed of incorporation of autogenous bone. To date, the heterogenous bone grafts have been used in nine patients with bone cysts; in all of the patients, satisfactory incorporation of the graft material has taken place.

The 1956 Meeting is to be held at the Cloisters, Sea Island, Georgia, under the presidency of Dr. J. T. Jacobs of Charlotte, North Carolina.

MEDICAL SOCIETY OF THE STATE OF NEW YORK

SECTION ON ORTHOPAEDIC SURGERY

AS REPORTED BY EMANUEL B. KAPLAN, M.D., NEW YORK, N. Y.

The Section on Orthopaedic Surgery of the Medical Society of the State of New York met in Buffalo, May 11, 1955, under the presidency of Dr. William E. Gazeley. The meeting was very well attended, the program was varied, and the papers were discussed from the floor and platform by members of the Section.

Vertebral-Body Biopsy. **DR. FREDERICK S. CRAIG**[1] presented a color motion picture demonstrating the technique in use at the Columbia-Presbyterian Medical Center in biopsy of various segments of the vertebral column. The importance of this type of investigation was well presented.

In the discussion that followed, extensive confirmation was presented by **DR. GLENN H. LEAK**[2].

Repair of Herniae through Iliac-Crest Defects. **DR. DAVID M. BOSWORTH**[3] described an ingenious method of repairing herniae through defects in the iliac crest which are observed in such rare instances as in cases in which the mid-portion of the ilium, including the crest, has been used as a donor area for bone grafts in other locations. The disabling herniae that develop through the defects in the ilium were well corrected by transplantation of the anterior part of the ilium with the muscles attached. The resulting occlusion of the herniation locus was successful in the three cases presented by Dr. Bosworth.

DR. FREDERICK L. LIEBOLT[4], in the discussion that followed, emphasized the rarity of this type of herniation.

The Surgical Management of Shoulder Conditions. **DR. H. F. MOSELEY**[5] presented a comprehensive review of treatment of shoulder conditions frequently encountered in orthopaedic practice. Many slides illustrated comprehensively the author's conceptions of pathology and treatment.

In the discussion that followed, **DR. ROBERT L. PATTERSON**[6] stated that his experiences were very similar to the experiences of Dr. Moseley.

The Conservative Management of Shoulder Conditions. **DR. A. A. MICHELE**[7] reported on the conservative treatment of shoulder conditions. The wide gamut of shoulder disabilities was analyzed. Dr. Michele believes that the deep cervical fascia, as shown in the anatomical textbooks, is involved in an inflammatory process which causes various painful syndromes. Procaine injections, iontophoresis, rest, traction, and various physiotherapeutic methods, followed by motion, are responsible for the success in relieving pain and symptoms.

[10] Bowman Gray School of Medicine, Winston-Salem, North Carolina.
[1] 180 Fort Washington Avenue, New York 32, N. Y.
[2] 375 Linwood Avenue, Buffalo 9, New York.
[3] 742 Park Avenue, New York 21, N. Y.
[4] New York Hospital, 525 East 68th Street, New York, N. Y.
[5] Royal Victoria Hospital, Montreal, Canada.
[6] 148 East 65th Street, New York 28, N. Y.
[7] 166 Clinton Street, Brooklyn, New York.

Dr. Harrison L. McLaughlin [8] discussed the pathology of certain shoulder conditions which were not directly connected with the deep fascia. **Dr. Robert Lee Patterson** [8] wished to know whether Dr. Michele had made studies of biopsy specimens to determine whether or not the fascia was involved in any inflammatory process; some phases of the treatment were not entirely acceptable to Dr. Patterson.

Dr. R. D. Severence [9] also participated in the discussion of Dr. Michele's paper.

Primary Vertebral Osteophytosis. **Dr. E. M. Bick** [10] pointed out the significance of the generalized osteophytic outgrowths of the vertebral column and the relation of this condition to strains of the spine at the insertion of the vertebral longitudinal ligaments. They may appear in many spine lesions in which there is strain on the ligaments or in certain conditions of postural strain. These outgrowths caused by strain must be differentiated from those with pathological manifestations.

Dr. Frederick R. Thompson [11] indicated the significance of osteophytosis in the vertebral column as a result of stress conditions of the ligaments of the spine. The relation of the osteophytosis to various pathological changes was discussed. He also indicated that arthritis of the spine is not necessarily associated with the presence of osteophytosis.

Dr. R. D. Severence [9] emphasized the importance of Dr. Bick's conclusions in relation to proper differential diagnosis and discussed the necessity for further study of the actual production of osteophytes by strain.

In the Executive Session, Dr. William E. Gazeley was elected Delegate, Dr. James P. Cole was elected Secretary, and Dr. Emanuel B. Kaplan was made Chairman of the Orthopaedic Section.

TEXAS ORTHOPEDIC ASSOCIATION

The Texas Orthopedic Association held its Annual Meeting under the presidency of Dr. Brandon Carroll in Forth Worth, Texas, on April 25, 1955. The scientific program included the following:

Surgical Treatment of Chronic Sprain of Ankle Caused by Displaced Detached Bone Fragment — Report of Four Cases by Dr. Dudley W. Smith, Harlingen.
Experience with Contrast Discograms by Dr. Charles F. Clayton, Fort Worth.
Conditioned Reflex Bracing by Dr. Herbert E. Hipps, Waco.
Primary Bone-Graft Treatment of Fractures of the Tibia by Dr. Philip L. Day, San Antonio.
Inherently Painful Soft-Tissue Tumors of the Extremities by Dr. William H. Bickel, Rochester, Minnesota.
Coccidioidal Granuloma of Bone by Dr. Henry C. McDonald, Jr., Fort Worth.
Hereditary Multiple Diaphyseal Sclerosis by Dr. H. H. Brindley, Temple.
Fracture of the Astragalus—Case Report by Dr. R. K. Gassler, Waco.
Use of Cultured Calf Bone Grafts in Orthopaedic Surgery by Dr. E. J. Tucker, Houston.
Total Scapulectomy—Foreign-Body Reaction on the Forearm—Case Reports by Dr. Louis J. Levy, Fort Worth.
Patella Transplants for Depressed Fracture of Lateral Tibial Plateau by Dr. Rex J. Howard, Fort Worth.
Spinal Cord Tumor by Dr. William H. Morgan, Fort Worth.
Erwin Procedure (Motion picture) by Dr. Gerald S. Ahern, Corpus Christi.

The officers elected for the coming year were:
President: Dr. Paul Williams, Dallas;
Vice-President: Dr. G. G. Gill, Beaumont;
Secretary: Dr. Margaret Watkins, Dallas.

NEW JERSEY ORTHOPAEDIC SOCIETY

The Spring Meeting of the New Jersey Orthopaedic Society was held at Jersey City Medical Center, Jersey City, New Jersey, on Saturday, April 30, 1955, with Dr. Harold C. Benjamin as Program Chairman and Moderator. The following scientific papers were presented:

Early Ambulation in Bilateral Fractures of the Tibia and Fibula Treated by Rush-Nail Fixation by Dr. Joseph J. Ruvane, Jersey City. Discussion by Dr. Otto Lehmann, Long Branch;

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[8] 180 Fort Washington Avenue, New York 32, N. Y.
[9] Medical Arts Building, Syracuse, New York.
[10] 30 East 60th Street, New York 22, N. Y.
[11] 16 East 90th Street, New York 28, N. Y.

(Continued on page 890)

News Notes

The next Annual Meeting of the **Western Orthopedic Association** will be held at the Reef Hotel, Honolulu, Hawaii, from November 7 to 10, 1955, under the presidency of Dr. J. Warren White.

The Eleventh Annual Meeting of the **American Society for Surgery of the Hand** will be held at the Palmer House, Chicago, Illinois, on Friday, January 27, 1956.

The Second Annual Meeting of the **Orthopaedic Research Society** will be held at the Palmer House, Chicago, Illinois, January 28, 1956.

The next Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held, under the presidency of Dr. Walter P. Blount, at the Palmer House, Chicago, Illinois, January 28 to February 2, 1956.

The next Annual Meeting of **The American Orthopaedic Association** will be held at the Banff Springs Hotel, Banff, Alberta, Canada, from June 20 to 23, 1956.

The Eighty-third Annual Meeting of the **American Public Health Association** and forty related organizations will be held at the Municipal Auditorium, Kansas City, Missouri, from November 14 to 18, 1955.

The Eleventh Meeting of the **Sociedade Brasileira de Ortopedia e Traumatologia** which was scheduled for June 1955 has been postponed to July 1956. It will be held in Porto Alegre.

The Annual Meeting of the **American Academy for Cerebral Palsy** will be held under the presidency of Dr. Lenox D. Baker in Memphis, Tennessee, October 10, 11, and 12, 1955. The meetings are open to members of the medical profession and allied professions who are interested in cerebral palsy. The three-day program will include instructional courses in the various phases of cerebral palsy and its treatment, as well as a formal scientific program. Those who wish to attend may obtain an invitation from Dr. Robert A. Knight, 869 Madison Avenue, Memphis 3, Tennessee. Hotel reservations are to be made directly with Mr. Scott Stewart, Manager of the Claridge Hotel, Memphis, Tennessee, which is convention headquarters.

The American Board of Orthopaedic Surgery has announced that the final date for filing application for the Part II examination to be given in January 1956 is August 15, 1955. Application should be made to Dr. Harold A. Sofield, Secretary, 116 S. Michigan Avenue, Chicago 3, Illinois.

The Sixty-second Annual Convention of the **Association of Military Surgeons of the United States** will be held at the Hotel Statler, Washington, D. C., from November 7 to 9, 1955. The Sir Henry Wellcome Medal and Prize, the Gorgas Medal, the Stitt Award, the McLester Award, the Louis Livingston Seaman Prize, and the Founders Medal will be presented.

The Annual Convention of **The National Society for Crippled Children and Adults** will be held at the Palmer House, Chicago, Illinois, from November 28 to 30, 1955. For information please write to: The National Society for Crippled Children and Adults, 11 South LaSalle Street, Chicago 3, Illinois.

At a recent meeting, the **Washington Orthopaedic Club** of Washington, D. C., elected the following officers for the coming year:

President: Dr. Everett J. Gordon;
Vice-President: Dr. John Adams;
Secretary-Treasurer: Dr. Marvin Gibson.

Dr. T. Campbell Thompson has been appointed Professor of Clinical Surgery (orthopaedics) of Cornell University Medical College and Surgeon-in-Chief of The Hospital for Special Surgery, New York City. As Professor of Clinical Surgery, he will be in charge of the Division of Orthopaedics for The New York Hospital-Cornell Medical Center. In its new location, The Hospital for Special Surgery provides the orthopaedic service for the entire Center.

Dr. Thompson succeeds Dr. Philip D. Wilson, who retired on July 1 from the position of Surgeon-in-Chief; Dr. Wilson has now become the Hospital's Director of Research and Education.

As guest of the Japanese Medical Association and of the Japanese Government, Dr. David M. Bosworth of New York City was one of the main speakers at the **14th Asian Congress of the Japanese Medical Association** held in the ancient city of Kyoto, Japan, from April 1 to 5, 1955. His subject was "The Use of Iproniazid and Marsilid in Bone and Joint Surgery".

Dr. M. Josiah Hoover has recently been appointed Chairman of the Orthopaedic Department of the Medical College of Virginia to fill the vacancy created by the death of Dr. H. Page Mauck.

KAPPA DELTA AWARD

A prize of $1,000.00, donated by the **Kappa Delta Sorority,** is offered annually by The American Academy of Orthopaedic Surgeons for the best research related to orthopaedic surgery, and performed by an American citizen in the United States.

Selection for the current year will be made from publications after January 1, 1953, or research presented to the Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons before November 1, 1955.

Researchers interested in competing may secure information from the Chairman of the Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons, Dr. Paul R. Lipscomb, 200 First Street, S.W., Rochester, Minnesota.

The **New Jersey Orthopaedic Society** has announced that it will make an award annually of $100.00 in cash for the best original paper in the field of orthopaedic surgery by an intern or resident (in any field) in a New Jersey hospital. The paper may cover any aspect of the field, such as pathogenesis, pathology, diagnosis, or treatment. The work on which this paper is based must have been done during, and completed not later than six months after, internship or residency in a New Jersey Hospital. For the current award the paper should be submitted to the secretary of the Society, Dr. Arthur S. Thurm, 533 West State Street, Trenton 8, New Jersey, not later than January 15, 1956. The award will be announced in sufficient time to permit inviting the winner to present his paper personally at the Spring Meeting of the Society.

PROCEEDINGS

NEW JERSEY ORTHOPAEDIC SOCIETY

(Continued from page 888)

Scoliosis: Review of Treatment with the Lateral Flexion Apparatus by Dr. Vincent Scudese, Newark. Discussion by Dr. Alvin Arkin, New York, N. Y. (by invitation);

Observations on the Use of Staples in Surgery about the Shoulder by Dr. Andrew Ruoff, III, Paterson. Discussion by Dr. Carl Maxwell, Morristown;

Unusual Carpal Injuries by Dr. Herman Frank and Dr. Francis Boyle (by invitation), Bayonne;

Results Following Resection of the Elbow for Tuberculosis by Dr. Herbert M. Simonson, Newark. Discussion by Dr. Alfred J. D'Agostini (by invitation), Newark;

Flexion-Adduction Deformity at the Hip in Spastic Paraplegia: A Method of Treatment by Dr. Harry Merliss, Hackensack. Discussion by Dr. Leonard Harris, Newark;

Calcified Tendinitis, Other Than at the Shoulder by Dr. Marshall Bergen, Jersey City. Discussion by Dr. Keith E. Haines, Camden;

The Present Status of Kenny Therapy: Method of Prevention and Treatment of Orthopaedic Deformities in Poliomyelitis by Dr. Marvin A. Steven, Visiting Orthopaedic Surgeon, Jersey City Medical Center (by invitation); Dr. Claus Jungeblut, Professor of Biochemistry, Columbia University (by invitation); Dr. Robert Ward, Professor of Pediatrics, New York University—Bellevue Medical College (by invitation); and Dr. Walter Thompson, Professor of Orthopaedic Surgery, New York University—Bellevue Medical College (by invitation). Discussion by Lieutenant Colonel Robert J. Neville, Medical Corps, United States Army, Murphy Army Hospital, Waltham, Massachusetts.

Book Reviews

CHIRURGIE DE LA MAIN. Livre du Chirurgien. Éd. 2. Marc Iselin. Paris, Masson et C^{ie}, 1955. fr. 4, 800.

The second edition of *Chirurgie de la Main* is an entirely new book. The author states in his preface that a complete rewriting of a book is a hard task for the author and disappointing to the reader. The reader may feel that the present edition, like the preceding one, may be completely out of date in about five or six years. However, the necessity of frequent changes proves that surgery is a science more than an art, because works of art are more permanent.

This is a monumental book of 626 pages covering a wide range of surgical conditions of the hand. It is divided into three sections: (1) sequelae of trauma, (2) acquired afflictions, and (3) congenital malformations.

The first section is subdivided into ten chapters which start with a description of anatomical and clinical methods of diagnosis; this is followed by a discussion of methods of treatment. Separate chapters on lesions of skin, bone, joints, tendons, and nerves are added. This section has three more chapters on sequelae of amputations, reconstruction of the thumb and fingers, and replacement of the amputated hand.

The second section on acquired afflictions contains separate chapters on Dupuytren's contracture, tenosynovitis, arthritis deformans, and tumors of the hand.

The third section, devoted to congenital malformations, is composed of two chapters.

There are 325 illustrations in the text. Most of them are photographs illustrating numerous cases from the extensive collection of the author. A few chapters of the book were written by M. Vassitch, associate of Dr. Iselin.

The author is well known for his work on the hand. He believes that hand surgery, which requires simultaneous skill in plastic and orthopaedic surgery and in neurosurgery, should be practised by a good general surgeon. Tribute is paid to Sterling Bunnell for his pioneering and extensive work and for his contributions during World War II. The author justly credits him with the creation of the American Society for Surgery of the Hand (although he erroneously states that the Society was founded only three years ago).

It is evident that the author has a fair acquaintance with the American and British literature, although omissions are noted.

Many ingenious methods of treatment are described for lesions of the skin. Curiously enough, an instrument for procurement of skin grafts, very similar to the one known in the United States as Brown's dermatome, is described as "*dermatome de J. Gosset*". This instrument can be powered either by electricity or by a pneumatic motor.

The chapters on tendon repair and on treatment of nerve lesions are excellent. The subject is presented in its true light and the difficulties and discouraging results are frankly discussed. The pathology of lesions and changes of view in the concepts of treatment and interpretation form a well balanced part of the description of various lesions.

Chirurgie de la Main is a valuable contribution to surgery of the hand. Its translation into English would be of great service for surgeons who cannot read French.

Emanuel B. Kaplan, M.D.

LEGG-CALVÉ-PERTHES SYNDROME AND RELATED OSTEOCHONDROSES OF YOUTH. Charles Weer Goff, M.D. In association with Ned M. Shutkin, M.D., and Myerma R. Hersey. Springfield, Illinois, Charles C. Thomas, 1954. $10.75.

In this excellent monograph, the author has succeeded in covering all of the varied aspects of his study with comprehensive thoroughness. He begins by offering a full, unbiased, historical review of pioneer work in the field. He credits Legg with presenting the first paper on the subject in 1909. Calvé followed independently five months later with a much more complete study. Perthes, the next year, published a very much larger series of cases, including one that he had seen as early as 1903. From this sequence of discoverers, the author labels this condition as the "L-C-P Syndrome".

Detailed discussions of the nature of the condition are presented, with analyses of the numerous controversial factors. For treatment, the recumbency method originally prescribed by Danforth and now practised at the Newington Home is described and advocated. This method avoids complete immobilization and permits a full day of activity on specially adapted frames and scooters, but it prevents imposition of any weight on the hip joint. The sociological problems arising from such a regimen are fully discussed from emotional, psychological, and educational viewpoints.

Succeeding chapters include extensive material on every phase of the subject from genetics through growth, mechanics, blood supply, and x-ray interpretation. End results in forty-one cases followed over ten years are carefully analyzed. Fifty pages are devoted to brief summaries of the "other osteochondroses", together with photographs of each discoverer responsible for the patronyms. There is also a brief but informative appendix describing the Newington Home and Hospital for Crippled Children, from which this study arises. The volume is made complete by a foreword by the late Jacques Calvé.

All in all, it may be fairly said that an orthopaedic library would not be complete without this book, and that no study is likely to surpass it for years to come.

Charles H. Bradford, M.D.

LIVING BONE IN HEALTH AND DISEASE. Irving Stein, A.B., M.D., F.A.C.S., F.I.C.S., Raymond Stein, A.B., M.D., F.I.C.S., and Martin L. Beller, A.B., M.D. Philadelphia, J. B. Lippincott Co., 1955. $15.00.

Profusely illustrated, thoroughly documented, well organized, and with an exhaustive index, this book contains a wealth of information, in readily available form. Part I, entitled "Living Bone in Health", is a review of the physiology of bone, for the most part more than adequate; its chief fault is that more elementary material is included than is required for the remainder of the book. Exception may be taken to some aspects of the treatment of the subject matter; the authors, for example, refer to the parathyroids as a part of a closed system, conceived of as a square including the parathyroids, the kidneys, calcium, and phosphorus. Why bone, the subject of this book, and certainly a target for the parathyroid hormone, is omitted from the authors' system is not apparent.

Part II, entitled "Living Bone in Disease", is an excellent summary of the pathology, the clinical features, and the treatment of the disorders of bone. The chapter on Paget's disease, to which the senior author has devoted special attention over many years, is especially good, even though many clinicians will not accept all of the features of the treatment recommended.

Part III, entitled "Diagnostic Classification of Bone Diseases", is a tabulation of etiological, pathological, laboratory, and miscellaneous aspects of diseases of bone. The authors' concept of this part is that of a "periodic table" of bone affections, which "may well help the careful scientific worker to fill in the as yet unknown elements".

The book, without a conscious effort on the part of the authors to do so, highlights the difficulties in terminology with which the subject of the diseases of the skeletal system is beset. Thus the term *multiple endochondromatosis*, listed under *osteocartilaginous exostoses*, is favored to replace the time-honored *dyschondroplasia*. From the list of synonyms appearing under the name adopted for each disease, it would appear that the time has come for the profession to formulate and adhere to a standard terminology in this field.

The task of producing this book was a large undertaking and, in general, it was well done.

Marshall R. Urist, M.D.

BONE — AN INTRODUCTION TO THE PHYSIOLOGY OF SKELETAL TISSUE. Franklin C. McLean, Ph.D., M.D., and Marshall R. Urist, M.D. Chicago, The University of Chicago Press, 1954. $6.00.

Over a period of a good many years, Franklin McLean, William Bloom, and Marshall Urist, both individually and in cooperation, at the University of Chicago, made many significant studies in the field of mineral metabolism and the histophysiology of bone. The excellence and broad scope of these studies clearly indicate the benefits that are to be derived from the collaboration of individuals who are trained in different fields.

The studies made by these three investigators, and published in different journals over the years, provide the backbone for the small book with which this review deals. To have this work brought together, even in an abbreviated form, is enough to justify the publication of this book. In addition, however, the material has been expanded so as to provide at least an introduction to most aspects of the whole broad field of bone physiology. It is obviously impossible in a book of this size to achieve as complete a coverage as might be wished by many students of this subject, and this desirable end is achieved generally only when the book deals with one of the more special interests of the authors. The net result is that some sections of the book are more authoritative and comprehensive than others, but the continuity provided by the authors' attempts to give a broad coverage has made the book, as a whole, extremely stimulating.

As might be expected from Dr. McLean's field of interest, the sections dealing with bone salt, the dynamics of calcification, enzymes and bone, and mineral metabolism are particularly informative and up-to-date. Recent work on the nature of the crystals in bone and the electron microscopy of bone has been included. The section dealing with bone resorption is imaginative, but does not add much that is new. The problem of citrate and bone is considered. The sections on hormones and vitamins in relation to bone are necessarily very brief. The problem of bone induction is considered in some detail.

The illustrations though few in number are of excellent quality. The bibliography is good.

All those who are interested in the physiology of bone and mineral metabolism will thoroughly appreciate and enjoy this book.

Arthur Worth Ham, M.D.

TRANSACTIONS OF THE THIRTY-NINTH CONGRESS OF THE ITALIAN SOCIETY OF ORTHOPAEDIC AND TRAUMATIC SURGERY. Naples, October 13-15, 1954.

A prominent part of these transactions is a report on osteochondritis published in three good-sized volumes by Dr. C. Casuccio, Dr. Aldo Recine, and Dr. M. Paltrinieri. This problem is discussed by each of the authors at great length from the general and etiological, the pathological and roentgenological, and from the therapeutic and statistical points of view.

Le Osteocondriti. Generalita — Eziopatogenesi. C. Casuccio. *Relazione al XXXIX Congresso della Società Italiana di Ortopedia e Traumatologia, Napoli, 13-15 ottobre 1954.*

While the title implies only the general and etiological aspects of the problem of osteochondritis, the treatise goes extensively into definition, nomenclature, frequency, and classification and then proceeds to the pathology of the essentials of aseptic necrosis. It is based upon a background of the most elaborate and painstaking study of the global literature and upon a large correspondence with some of the most prominent authorities. In general, the author accepts the current definition of osteochondritis as an aseptic necrosis of primary or secondary ossification centers, which occurs during growth and which has a tendency toward spontaneous cure, very often with deformity. The author, however, believes that aseptic necrosis does not in every case represent the essential cause of the condition. What distorts the picture somewhat is his including in his table of classification infectious conditions which, by definition of aseptic necrosis, do not belong there. However, when he treats the subject, he considers only the aseptic condition as such. There is a good illustration of diverse localizations of this ubiquitous condition, attached to which is the lengthy row of names of the discoverers. There is also a table on relative frequency. Among fourteen different forms of the conditions, Perthes' disease naturally occupies the foremost place with a frequency of 49 per cent. in the author's series and of about 30 per cent. in a collective series, the latter embracing 1,268 cases.

The analysis of osteochondritis in general occupies the first part of the book; the author discusses heredity, the essential pathological features, and experimental studies on production of osteochondritis by trauma and circulatory damage, both from sources in the literature and from his personal studies. His own experiments, made on rabbits, are based on section of the ligamentum rotundum, on resection of pelvitrochanteric muscles, and on section of the capsule. His conclusion is that osteochondritis in man has diverse causes, circulatory as well as traumatic, metabolic, and endocrine. In the following section the author expatiates more freely on the different theories on the etiology of osteochondritis: the rachitic theory, the theories of congenital dysplasia or osteitis fibrosa, the endocrine, metabolic, neurogenic, vascular, static, and traumatic theories, not forgetting Waldenström's infectious theory of 1909. The difficulty with these theories is usually that they are not mutually exclusive and, therefore, can be applied concurrently and in combination.

The second part of this work is even more interesting. It deals with specific localizations. It begins duly with osteochondritis of the hip, to which a great deal of pathological and clinical consideration is devoted, with the usual long reference to contributions in the literature. This is followed by a discussion of Osgood-Schlatter disease, with some interesting pathological details added which are not usually recorded. The following chapters deal with the more rare conditions, among them osteochondritis of the patella, of which three cases are reported.

Haglund's osteochondritis of the calcaneal epiphysis is also presented under a profusion of names. The author has collected 114 cases from the literature, adding two of his own. In both of these conditions, the traumatic element looms large as the underlying cause. The same concept is expressed in the discussions which follow, of Köhler's disease of the tarsal navicular and in the disease of Köhler-Freiberg where also preference is given to traumatic over circulatory and constitutional factors. However, in discussing kyphosis adolescentium or Scheuermann's disease, the author admits that there must be certain individual predispositions without which the manifestation of the disease would be hard to explain. Whether these predisposing factors are of endocrine, rachitic, or other origin is a question which is left open. At any rate, a condition of lessened resistance exists based on an intrinsic or constitutional element upon which the extrinsic factor of mechanical stresses is superimposed or to which it is coordinated.

Kienböck's disease is presented as a traumatic rarifying osteitis, with emphasis on cystic cavities, the abundance of intertrabecular connective-tissue necrosis of trabeculae in a state of resorption, and islands of cartilage between fibrous tissue and bone. While genetic elements are admitted, the relation to trauma is again stressed. Osteochondritis of the ischiopubic joint described by Delitala and Valtancoli, as well as other rare localizations, such as the clavicle, the upper portion of the humerus, the elbow, and the condyles and epicondyles are cited. There is also mentioned osteochondritis of the sacro-iliac joint, of the iliac spines, the greater trochanter, lower end of the femur, upper end of the tibia, the cuneiforms, and the sesamoids. No less than twenty-three of these rare localizations are quoted from reports in the literature.

Le Osteocondriti. Anatomia Patologica. Quadri Clinici e Radiologici. Aldo Recine. *Relazione al XXXIX Congresso della Società Italiana di Ortopedia e Traumatologia, Napoli, 13-15 ottobre 1954.*

This report is devoted principally to the pathological and roentgenological aspect of the osteochondritides. It begins with a detailed description of normal histology and ossification, illustrated by excellent high-power and electron-microscopic pictures. The latter are particularly interesting. They demonstrate collagen fibers under magnifications up to 83,000.

Another chapter deals with the general pathological anatomy of osteochondritis, information being derived from occasional postmortem material and more often from tissue obtained at operations and biopsies. A number of essential features are brought out: the deformation of the femoral head, the long preservation of the joint cartilage, the thickening of the ligaments, and the changes in the synovial tissue; final fissuring and other late degeneration of the cartilage are also mentioned. Notice is also taken of the intense vascularization of synovial tissue, and many other features are discussed. Usually the author is in accord with generally accepted views. The photomicrographs are unusually good, especially those which illustrate the relation between collagen fibers and ground substance. Others show the vascularization of cartilage cells, the penetration of vascular connective tissue into the zones of provisional calcification, the perivascular infiltrations and thickening in really beautiful illustrations.

It was not an easy thing for the author to present an over-all clinical picture of a condition which presents itself in so many different localities. In this respect, the author can hardly go beyond the general statements on age, heredity, distribution, and local signs. In a following chapter, however, a good point is made by demonstrating roentgenographic signs which precede clinical symptoms.

The different phases forming the cycle of necrosis and creeping substitution are well presented from the roentgenographic point of view. Naturally the most substantial part of this report is that which deals separately with the various forms and locations of osteochondritis. Here, as might be expected, osteochondritis of the hip is given the place of pre-eminence. No particularly new features are introduced into the description of the morphological changes, but the photomicrographs showing cartilage, bone, circulatory, synovial, capsular, and nerve changes are excellent and unusually well selected, as are the x-ray studies relating to the course and outcome of Calvé-Perthes disease, of which several good follow-up roentgenograms are shown. Some of these demonstrate convincingly the deformation of the head and the late arthrosis which follows. The reader will meet with the same thoroughness in the discussion of Osgood-Schlatter disease, of osteochondritis of the patella, of Scheuermann's disease of the spine, and of the less frequent Haglund, Köhler, Köhler-Freiberg, and Kienböck's disease.

The more unusual localizations are described in the final chapter; they include such sites as the talus, the os pubis, the phalanges, the sacro-iliac joint, and others, although in some of these it may be difficult to demonstrate the aseptic necrosis, as is the case, for instance, in the sacro-iliac joint, or in the phalanges.

Le osteocondriti giovanili. Cura ed esiti. M. M. Paltrinieri. *Relazione al XXXIX Congresso della Società Italiana di Ortopedia e Traumatologia, Napoli, 13–15 ottobre 1954.* Firenze, Vallecchi Editore, 1954.

This is the last of the three large reports on the subject and also covers all types of osteochondritis, as do the previous reports. In his discussion, the author makes the pertinent remark that a great deal of confusion arises from the fact that the various contributors display the tendency of making a different nosological entity out of almost every case reported. Only a proper grouping of the cases, accompanied by better knowledge of the pathological background, is able to clarify the situation.

After discussing at length the different concepts which are expressed in the literature, the author states his own views, according to which osteochondrosis juvenilis is based on stress or fatigue fractures of the centers of ossification, on the order of Looser's zones, and that the subsequent transformations are based on the discrepancy which exists between resistance and stress. In a special section of the book, this concept is further applied for the different sites of osteochondritis. The first is Perthes' disease, which is also, according to the author, the result of stress fracture. He bases his opinion on statics and muscle stress without, however, going into the question of the selectiveness of the condition. The description of the treatment which he offers is lost in a collection of information obtained from the literature without definite preferences being stated. The same interpretation is given to post-reduction osteochondritis of the hip in congenital dislocation; as is consistent with this view, the abduction treatment in the predislocation phase and open reduction for irreducible or recurrent dislocation appears to be the author's procedure of choice. From this mechanical concept, the logical conclusion is drawn that any patient who has recovered from Perthes' disease is a potential candidate for arthrosis of the hip, a concept to which little objection can be offered.

Another chapter is devoted to Köhler's osteochondritis of the tarsal navicular. Here also the condition is reviewed as a juvenile osteochondrosis based on disequilibrium or disparity between stress and resistance which leads to fatigue fracture.

The same attitude is observed in regard to Köhler-Freiberg disease of the metatarsal head, a condition which also heals in time only to end, like Perthes' disease, in arthrosis. In this particular situation, the author believes in the surgical resection of the head which he has himself carried out in six cases and which, according to him, gives excellent results without disturbing the statics or dynamics of the foot.

The author follows up his traumatic concept in the following chapters, which deal with Osgood-Schlatter disease. He accordingly advocates immobilization in a cast during the painful phase as the treatment of choice. There can be no objection to his attitude nor to his rejection of surgical measures, such as resection of the tibial apophysis or even of metallic fixation.

In the section on Haglund's disease, the same idea of its purely traumatic character as a stress phenomenon is expressed. In consequence, there is the same adherence to conservative treatment. The author definitely states that surgical interference is unjustified — a point with which most of us will agree. Where the traumatic theory of the author is more difficult to accept is in the following chapter on osteochondritis vertebralis or the so-called Delahaye-Scheuermann disease.

This imposing trilogy of reports is a most formidable achievement in point of thoroughness and comprehensiveness. The authors are particularly to be credited with a most careful study of the literature and the attention they paid to the numerous and divergent views in regard to the etiology and the treatment of the different conditions. The extent of the authors' work is clearly demonstrated in their bibliography. This, in fact, is so extensive that a special volume is devoted to the references alone, which contains probably well over 1,500 different items coming from many countries. It is a monumental work and a great testimony to the thoroughness and industry of the authors.

Arthur Steindler, M.D.

PERIPHERAL NERVE INJURIES. By the Nerve Injuries Committee of the Medical Research Council. Edited by H. J. Seddon. (Privy Council. Medical Research Council Special Report Series. No. 282.) London, Her Majesty's Stationery Office, 1954. 2 pounds, 15 shillings.

This valuable book of 451 pages and 276 illustrations contains in many separate chapters careful and thorough reviews of the investigations and work which have been done in the five Nerve Injury Centres in England and the two in Scotland; these Centres have cared for 4,000 cases of nerve injury.

About fifteen separate articles are included, mostly by the associates of Prof. Seddon and largely from the Oxford Centre where extensive and careful work has been done in repairing nerves.

Seddon tells of the standard methods of examining for nerve injury and of recording recovery. He also discusses thoroughly the value of nerve autografts based on his many tabulated cases and the work of his colleagues. His enthusiasm for autografts is well documented.

Sanders shows the value of autografts by photographs illustrating the histopathology and by tabulations of the many cases.

Ruth Bowden writes on the rates of regeneration, the factors influencing functional recovery, and electromyography. She has factually reported the poor results, as well as the good, and has well illustrated the histopathology of the changes in both the muscle and the peripheral-muscle nerve segment. She is not yet convinced of the value of electromyography in routine examinations of injured nerves.

Zachary deals with lesions in continuity, classifies the degree of nerve injury as a guide to indications for surgery, and lists by means of a code system the results of their many repairs of nerves. With guarded enthusiasm he gives nutrition, delay of suture, and length of gap as the three factors that most influence the repair.

Blackwood and Holmes well illustrate the histopathology of nerve injuries, both in animals and man.

Brooks tells of nerve injury by fractures, stating that nine of ten nerve injuries recover without surgery. He gives a rather gloomy report of the success of repair of the brachial plexus.

Barnes writes on the subject of causalgia, stating that presympathetic sympathectomy is the best treatment.

Richards deals with vasomotor and nutritional disturbances and neurovascular lesions. The early warmth in trophic changes he ascribes to paralysis of the vasomotor nerves; the later coldness he ascribes to constriction from the use of adrenalin. He shows that injury to both arteries and nerves results in ischaemic contracture and, in half of the cases, some peripheral gangrene.

Ritchie covers electrical diagnosis.

Sterling Bunnell, M.D.

PRAXIS DER BEGUTACHTUNG UNTER BESONDERER BERÜCKSICHTIGUNG DER UNFÄLLE. Versicherungsrecht, Untersuchungstechnik, Einschätzung. Oberarzt Dr. Simon Mayr. Wien, Verlag Wilhelm Maudrich, 1954. $6.00.

Dr. Mayr points out in this book that there is in Austria an overwhelmingly high percentage of disabled persons about 500,000 of whom are war casualties. The object of Dr. Mayr's book is to teach non-experienced physicians the necessary fundamentals of evaluating disability. He divides this book into three parts. In the first part, he deals with accidental injuries covered by insurance and the responsibilities of the physicians who treat such injuries. In the second part, he presents in detail the method of examining the patient applying for disability compensation. The orthopaedic aspect in the injuries of such patients is emphasized. In the third part, he describes the various methods of examining single parts of the body and demonstrates instruments for measuring motion and for measuring the extent of function. He suggests ratings for disability to single parts of the body and includes ten tables in which parts of the hand and the fingers are rated in percentages of disability.

The book is very instructive and it will be of interest to physicians who are interested in the subject of disability evaluation.

Earl D. McBride, M.D.
Basilius Zarichznyj, M.D.

DIE OBJECTIVE STEREOSKOPIE AN RÖNTGENBILDERN. Eine diagnostische Methode. Prof. Dr. A. Hasselwander. Stuttgart, Georg Thieme Verlag, 1954. DM 27. —; $6.40.

This book is a rather voluminous essay on roentgenographic stereoscopy. It is divided into two major parts, the first dealing rather extensively with the physical and optical features of stereoscopy and the second dealing with the clinical application of this method. The first part will be of interest to those who would like to know the physical and optical applications of stereoscopy, and it will explain many of the intricate features related to stereoscopic vision. In the second part the author elaborates extensively on the possibilities for which stereoscopic roentgenography is suitable. While he expresses profound knowledge of this method of roentgenographic study, his ideas represent a great overestimation of a method which has found only restricted use in this country. All American roentgenologists will agree that stereoscopic roentgenography is a useful procedure but of limited need, — necessary only for the evaluation of specific problems. The author, in contrast, seems to feel that objective stereoscopy in roentgenology should play a more important role and recommends its use for many procedures in which the usual routine films of two-dimensional projections will bring about satisfactory, and often even better, results.

This book is extensively illustrated with pictures and sketches emphasizing the author's point of view and explaining the reason for his belief that stereoscopy is such an important method. The reviewer believes that this book, to say the most, is of limited interest to only a few.

H. Peter Mueller, M.D.

DIE WIRBELSÄULENVERLETZUNGEN UND IHRE AUSHEILUNG. Pathologische Anatomie, Klinik, Röntgendiagnostik, Begutachtungs- und Zusammenhangsfragen. Prof. Dr. A. Lob. Stuttgart, Georg Thieme Verlag, 1954. DM 78. —; $18.55.

This book offers an interesting analysis of the traumatic conditions of the spine and of neighboring parts. The genesis and pathology of the various types of trauma are described, preceded by a brief description of the anatomy, function, and the constructive mechanism involved.

The mechanics of the various injuries are enumerated with particular reference to the dynamics of the external force in regard to trauma to the disc and the different bony portions of the vertebrae. Many interesting and rare types of injury are discussed, among more common ones, and are identified by interesting and unusual illustrations which add to the understanding of the text.

A large section of the book is devoted to the process of healing and the findings which one may encounter in older injuries and healed fractures. These are correlated to the type of injury, the length of time involved in healing, and the differential diagnosis between traumatic lesions and other types, including spontaneous or pathological fractures.

Of significance to an interested reader will be the chapters in which the types of examinations are described and suggestions are made for the correct positioning of the patient for the various x-ray views in order that the most may be obtained from an adequate roentgenographic examination. Extensively discussed is the evaluation of injuries in relation to industrial accidents and other accidents which may lead to legal action; the relation of such injuries to the factors of compensation and insurance law is explicitly evaluated. In this chapter are important points in regard to the differential diagnosis and possible errors and common errors in the evaluation of questionable roentgenograms. Although many of these chapters relate directly to German insurance and compensation laws, much information will be found for a reader dealing with different legal and compensation procedures.

This book presents a very timely addition to a roentgenographic and orthopaedic library. A great amount of valuable information will be found by those who have to deal with lesions of this type.

The text is easy to understand and the illustrations are excellent. A good index and bibliography add to the value of the book.

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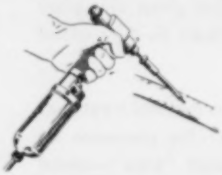

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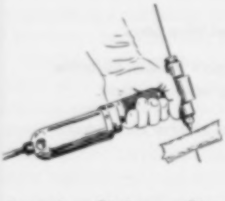

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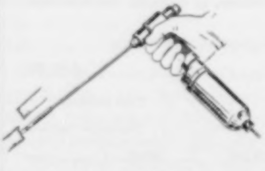

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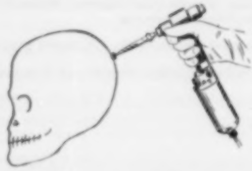

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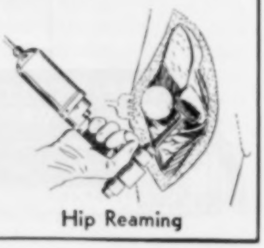

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This book is an attempt to eliminate the differences between the diverse viewpoints of those who, clinically and microscopically, roentgenologically and chemically, examine bone and bones and of those who experiment with bone and bones. It tries to bury once and for all the specters of "halisteresis or decalcification," "interstitial growth of bone," "physical plasticity," and "creeping replacement," which are resurrected again and again by the magic of the imagination.

In preparing the second edition the authors tried to apply the same general principles of biology to a consideration of the many advances which have since been made in the knowledge of the histology and biochemistry of the fascinating tissue we call bone. For the first time it seems possible to outline more fully a hypothetical mechanism of bone formation and resorption and to present a basic concept of skeletal growth, especially of the growth of the skull.

The first part has been enlarged by a discussion of some of the peculiar features of the otic capsule; to the second was added a discussion of osteoid osteomas and cementomas, of fibrous dysplasia of bone, and of some peculiar genetic disturbances of the skeleton.

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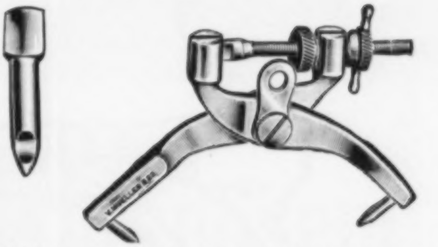

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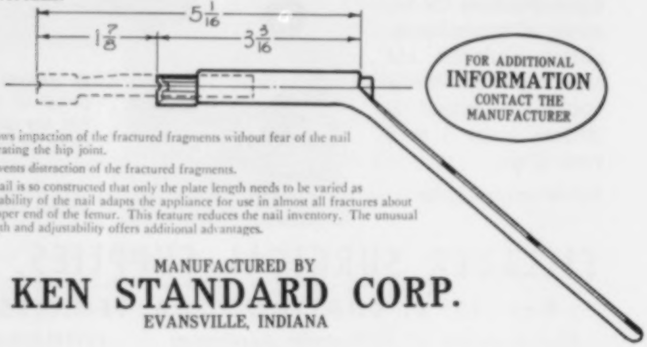

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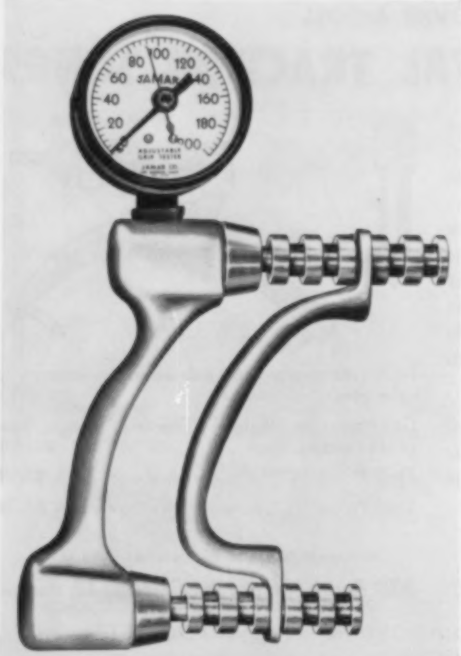

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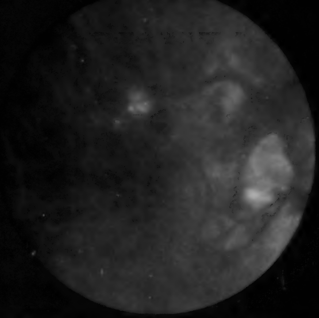

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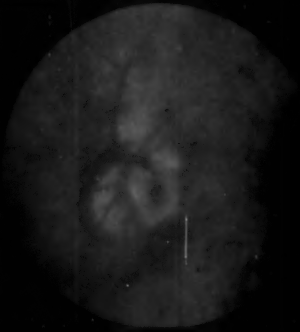
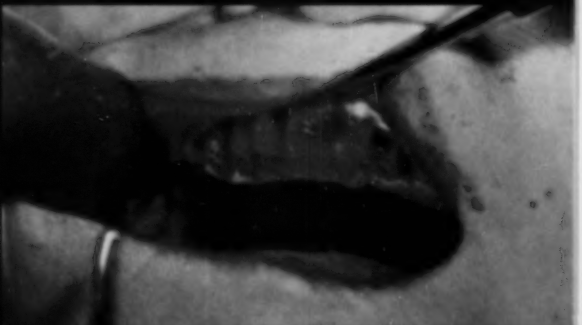


After Adrenosem therapy. Note exudative areas. Maintenance therapy checks further hemorrhage.

Mastoidectomy with a bloody field obscures view, requires frequent suctioning.

After Adrenosem therapy. Note clearer operative field with minimized bleeding.

Multiple extraction without Adrenosem. Note seepage. Frequent suctioning is required.



After Adrenosem therapy. Note clearer field. Minimal bleeding facilitates surgery and promotes healing.

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Adrenosem is specific for conditions characterized by increased capillary permeability allowing oozing and seepage bleeding. To prevent seepage bleeding due to capillary permeability it is necessary to maintain tone of the capillary wall. This is supported by Pappenheimer's[1] work on capillaries. In cases of capillary permeability it is postulated that the connective material between the cells, which form the capillary wall, has lost its tone and allows the erythrocytes to pass through.

To confirm the action of Adrenosem in establishing capillary integrity the cheek pouch of a hamster was irritated with snake venom, which has the property of making the capillaries more permeable.[2] A great many petechiae appeared on the surface and a 500 X magnification showed the capillaries with extravasation of erythrocytes. Another animal was treated with Adrenosem, and 30 minutes later, the same amount of snake venom was used to irritate the cheek pouch. Microphotographs of the same 500 X magnification show the intact capillary walls and the actual blood cells coursing through the capillaries, without signs of escaping erythrocytes.

Fig. 1—*Trauma from snake venom produces hemoconcentration and stasis, indicative of altered vascular permeability.*

Fig. 2—*Trauma does not produce petechiae following Adrenosem injection.*

action

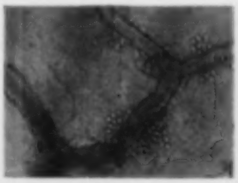

Fig. 1

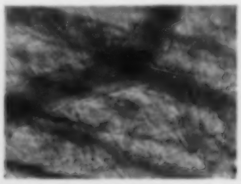

Fig. 2

A systemic hemostat, Adrenosem restores capillary integrity by maintaining tone of intercellular tissue in the capillary wall. Adrenosem is unlike any hemostat available to medicine.[3,4] It does not interfere in any way with the blood clotting mechanism or its component parts. There is no sympathomimetic action and the blood pressure, cardiac rate and volume are not affected. Adrenosem may be administered simultaneously with any type of anesthetic, anticoagulant or vitamin K and heparin. Adrenosem will not interfere with the action of these agents.

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1 *Pappenheimer, John R.: Passage of molecules through capillary walls, Physiol. Rev. 33:387-423, 1953.*

2 *Fulton, M. D., Department of Biology, Boston University: Personal communication, 1954.*

3 *Sherber, Daniel A.: Adrenochrome complex in the control of bleeding, Am. J. Surg. 86:331-335, 1953.*

4 *Roskam, J.: Arrest of Bleeding, Chas. C. Thomas, Publisher, Springfield, Ill., 1954.*

5 *Peele, J. G.: Adrenosem in the control of hemorrhage from the nose and throat (in press).*

6 *Bourgoyne, J. R. and Riddle, A. C., School of Dentistry, University of Tennessee: Personal communication, 1954.*

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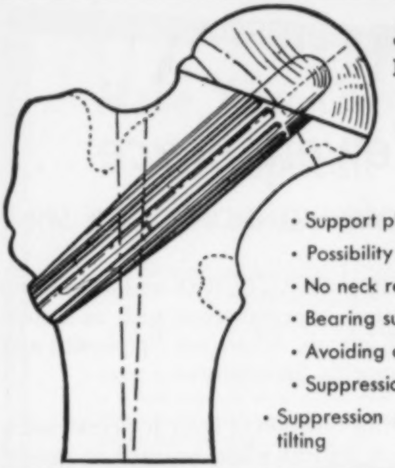

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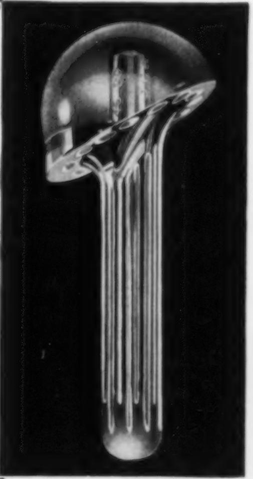

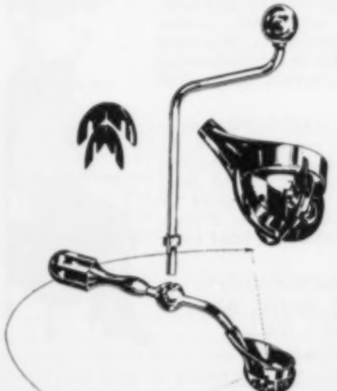

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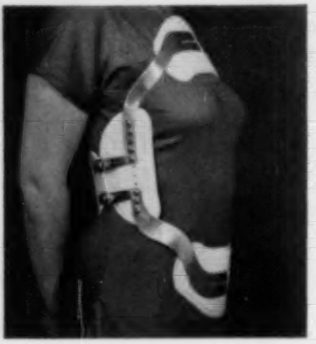

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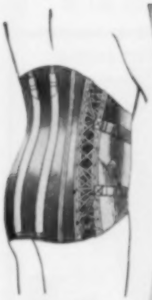

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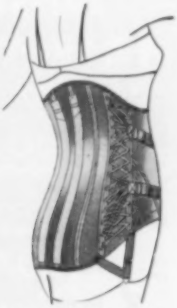

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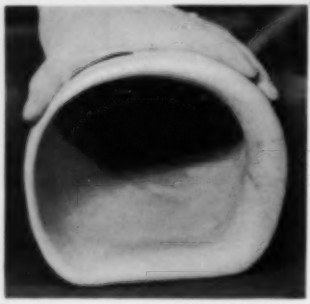

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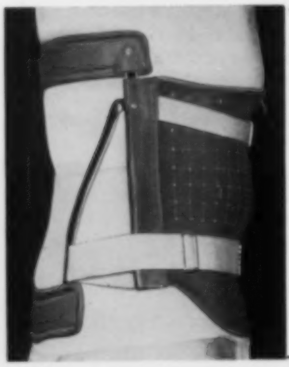

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LeRoy C. Abbott, M.D., University of California Hospital, Second and Parnassus Avenues, San Francisco 22, California
Robert W. Augustine, M.D., Trover Clinic, 55 East North Street, Madisonville, Kentucky
Mario Bonaquist, M.D., 622 Michigan Avenue, Schenectady 3, New York
David M. Bosworth, M.D., 742 Park Avenue, New York 21, N. Y.
Colonel Ernest A. Bray, Walter Reed Army Hospital, Washington 12, D. C.
Sterling Bunnell, M.D., 516 Sutter Street, San Francisco 2, California
Bruce M. Cameron, M.D., 5220 Travis, Houston 6, Texas
Samuel W. Chase, M.D., Western Reserve University School of Medicine, 10940 Euclid Avenue, Cleveland, Ohio
C. C. Chatterton, M.D., Gillette State Hospital for Crippled Children, 1003 Ivy Avenue, East, St. Paul 6, Minnesota
Jonathan Cohen, M.D., 300 Longwood Avenue, Boston 15, Massachusetts
Lawrence M. Demarest, M.D., St. Luke's Hospital, New York 25, N. Y.
Dr. Jean Dunoyer, #3, square Desaix, Paris 15, France
J. William Fielding, M.D., 742 Park Avenue, New York 21, N. Y.
Willard F. Greenwald, M.D., Yale University Hospital, New Haven, Connecticut
Lee A. Hadley, M.D., State Tower Building, Syracuse 2, New York
Charles H. Herndon, M.D., 2065 Adelbert Road, Cleveland, Ohio
John M. Hundley, M.D., 412 Cross Street, Little Rock, Arkansas
Dr. P. M. Jantzen, Orthopädische Universitätsklinik, München-Harlaching, Germany
Floyd Jergesen, M.D., 384 Post Street, San Francisco 8, California
Dr. Jean Judet, #3, square Desaix, Paris 15, France
Dr. Robert Judet, #3, square Desaix, Paris 15, France
Jacob F. Katz, M.D., 30 East 60th Street, New York 22, N. Y.
Harold D. Kletschka, M.D., State University of New York, 451 Clarkson Avenue, Brooklyn 3, New York
Pierre Lacroix, M.D., Institut d'Anatomie, Université de Louvain, Louvain, Belgium
Dr. J. Lagrange, #3, square Desaix, Paris 15, France
Bernard Levowitz, M.D., State University of New York, 451 Clarkson Avenue, Brooklyn 3, New York
Wm. R. MacAusland, Jr., M.D., 412 Beacon Street, Boston, Massachusetts
Frank O. McGehee, M.D., 5220 Travis, Houston 6, Texas
John G. McNamara, M.D., 142 Joralemon Street, Brooklyn 1, New York
Henry Milch, M.D., 225 West 86th Street, New York 24, N. Y.
Richard D. Mulroy, M.D., 1101 Beacon Street, Brookline 46, Massachusetts
Walker Reynolds, Jr., M.D., 305 East 10th Street, Anniston, Alabama
Howard Rosen, M.D., 2 Fifth Avenue, New York 11, N. Y.
Alvina O. Sabanas, M.D., 6725 South Paxton Avenue, Chicago 49, Illinois
Herbert Sandick, M.D., 222 South Street, Pittsfield, Massachusetts
Dr. W. Schumpelick, Hafenkrankenhaus, Hamburg, Germany
Robert S. Siffert, M.D., 941 Park Avenue, New York 28, N. Y.
Marcus J. Stewart, M.D., 869 Madison Avenue, Memphis 3, Tennessee
Mr. William Wagenseil, 115 South Portland Avenue, Brooklyn, New York

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